BIOCHEMICAL, RAW, AND COOKED COLOR CHARACTERISTICS OF INDIVIDUAL BOVINE MUSCLES IN OXYGEN PERMEABLE AND MODIFIED ATMOSPHERE PACKAGES

A Dissertation

by

PATRICK DANIEL MIES

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2003

Major Subject: Animal Science

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Approved as to style and content by:

Jeffrey W. Savell (Chair of Committee)	Dan Hale (Member)
Danny Klinefelter (Member)	Jimmy Keeton (Member)
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ABSTRACT

Biochemical, Raw, and Cooked Color Characteristics of Individual Bovine Muscles in Oxygen Permeable and Modified Atmosphere Packages. (December 2003)

Patrick Daniel Mies, B.S., Texas A&M University;

M.S., Colorado State University

Chair of Advisory Committee: Dr. Jeffrey W. Savell

Color stability and cooked muscle color were evaluated in relation to myoglobin content, oxygen consumption rate, pH, lipid oxidation, oxygen penetration depth, metmyoglobin reductase activity, Hunter L*- a*- b*- values, discoloration, and degree of doneness for the *M. Infraspinatus* (IF), *M. Triceps brachii* (TB), *M. Teres major* (TM), *M. Rectus femoris* (RF), *M. Vastus lateralis* (VL), *M. Semimembranosus* (SM), *M. Biceps femoris* (BF), *M. Semitendinosus* (ST), *M. Gluteus medius* (GM), as well as the *M. Psoas major* (PM), and *M. Longissimus lumborum* (LL). Steaks from these muscles were segmented into a low oxygen dark, low oxygen light, high oxygen, and PVC overwrap packaging environment for six days of retail display. There were no major differences in pH, oxygen consumption rate, or myoglobin reductase acitivity between shelf-life days and packaging environments for the muscles used in the study. The VL, TB, ST, SM, and the GM had higher levels of lipid oxidation in the later days of shelf-life storage and were higher ($P < 0.05$) in high oxygen packaging compared to the other three treatments. Oxygen penetration depth was greater ($P < 0.05$) over all storage days for the high oxygen treatment in the TB and LL as compared to the other treatments. Hunter CIE a* and b* values significantly decreased across all muscles for the high oxygen and PVC treatments. Discoloration increased significantly as storage days increased in the high oxygen and PVC treatments for the TB, SM, VL, BF, IF, GM, PM, and TM. Degree of doneness was higher ($P < 0.05$) for the PM, TB, and SM muscles in a high oxygen atmosphere as compared to the low oxygen light and low oxygen dark treatments. Aerobic reducing ability tended to decrease as retail shelf-life day increased. A high oxygen environment increased rancidity, oxygen penetration depth, redness values, and degree of doneness ($P < 0.05$) when compared to a low oxygen light and low oxygen dark modified atmosphere package.

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CHAPTER I

INTRODUCTION

Meat discoloration is well recognized as one of the leading causes of loss of sales at the retail meat case. Additionally, meat merchandisers discard or devalue millions of dollars worth of product because of discoloration. Thus, meat color is a major driver of retail meat case sales and profitability. Meat color and color stability have been important areas of research for a number of years. Researchers have identified a number of biochemical and physical factors that can affect color and color stability: metmyoglobin reductase activity (Renerre and Labas, 1987; Reddy and Carpenter, 1991), oxygen consumption rate and oxygen penetration depth (O'Keefe and Hood, 1982; Renerre and Labas, 1987), autoxidation (Renerre and Labas, 1987; Faustman and Cassens, 1990), partial oxygen pressure (Faustman and Cassens, 1990), and pH (Faustman and Cassens, 1990). Although our understanding of muscle color and the factors associated with discoloration have progressed during the past three decades, our understanding of the color characteristics of individual muscles within a beef carcass has not been thoroughly investigated.

Given the fact that case-ready beef is rapidly replacing traditional in-store cut and PVC overwrapped beef, and a trend towards marketing individual muscles based on their merits rather than muscle groups, a complete characterization of the color stability

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This thesis follows the style of the Journal of Animal Science.

characteristics is needed for those muscles to succeed into case-ready programs. The rationale for the proposed research is to discover how individual muscles vary in characteristics that dictate color stability and discoloration. Those characteristics that are identified as negative or positive can then be used in packaging environments that will minimize the effects of their negative characteristics and maximize the effects of their positive characteristics.

The objectives of this study were to:

Phase I

1. Quantify the biochemical and physical factors that dictate the color stability and rate of discoloration of major individual bovine muscles.

2. Determine the effect of retail display time on biochemical and physical factors that dictate the color stability and rate of discoloration of major individual bovine muscles.

3. Determine the color stability and response of biochemical and physical measures of individual bovine muscles in different packaging environments.

Phase II

4. Quantify the amount of surface discoloration and the color stability of individual muscles.

5. Determine the effect of packaging environments and retail display time on the cooked color characteristics of individual bovine muscles.

CHAPTER II

REVIEW OF LITERATURE

The bright cherry red color of fresh beef is one of the most important quality attributes in a consumer's mind when they purchase beef from a retail case. Research has indicated that physical appearance of a retail cut is the most important factor in a consumer's buying decision (Dunsing, 1959.) Additionally, meat merchandisers lose millions of dollars every year due to product discoloration. Thus, meat color is a major driver of retail meat case sales and profitability. Meat color and color stability have been important areas of research for a number of years. Color in meat is primarily dependent upon the redox state of the heme iron in myoglobin. When oxygen binds to the ferrous ligand of myoglobin, oxymyoglobin is formed producing the bright cherry red color associated with wholesomeness by consumers (Liu et al., 1995). However, the oxymyoglobin state is unstable and will oxidize to form ferric metmyoglobin or an unattractive brown color associated with spoilage (Renerre 1990). The transition from the oxymyoglobin state to the metmyoglobin state is called the shelf-life of meat.

There has been renewed emphasis on developing ways to improve shelf-life over the last decade. One of the methods that is in use today is modified atmosphere packaging (MAP), or case-ready meat. Case-ready meat has been evolving within the meat industry for a number of years. The adoption of case-ready beef programs by major meat retailers, such as Wal-Mart, has driven most major packing companies and retailers to incorporate case-ready programs into their production systems. Current figures estimate that 6-8% of retail meat products are sold in MAP packages, with the expectation that this percentage will grow exponentially in coming years (Hunt, 2002). Case-ready packaging systems allow for the use of modified atmosphere packaging MAP environments in addition to the traditional oxygen permeable polyvinylchloride-overwrap.

Modified atmosphere packaging has been utilized for retarding spoilage microorganisms as well as extending shelf life in beef, pork, and lamb. The two most common modified atmosphere systems used today are a high oxygen package with carbon dioxide and a low oxygen package with a high percentage of nitrogen gas. High oxygen packages are sealed with a film of low gas permeability in an individual tray, or case-ready tray. Conversely, several trays overwrapped with a highly permeable film may be placed in a master pack that has a high oxygen modified atmosphere (Taylor, 1985).

Carbon dioxide used in MAP has been shown to retard the growth of aerobic spoilage bacteria (Gill and Tan, 1980; Marshall et al., 1991; Wimpfheimer et al., 1990). Carbon dioxide will shift the microflora from a rapidly growing Gram-negative bacteria to a slower growing Gram-positive bacteria (Davies, 1995). Carbon dioxide is normally used in packaging at a level of 20 to 30% (Parry, 1993).

Nitrogen is commonly used as a filler gas to keep the film from contacting the product surface when carbon dioxide dissolves into the product (Gill, 1988). Red meat in a high oxygen MAP will take in oxygen to bind to myoglobin and form oxymyoglobin while releasing carbon dioxide. Therefore, the amounts of different gasses in the MAP environment will change over the shelf life of the product (Brown, 1992.) High oxygen MAP requires enough headspace of gas to buffer against the respiration of the product, making the package bulky in the retail counter. An alternative way to use MAP is through a low oxygen or oxygen depleted atmosphere.

Low oxygen atmospheres are mainly used in the vacuum packaging of primal and subprimal cuts. These cuts are then shipped to retailers where steaks or roasts are cut and displayed in an oxygen permeable polyvinylchloride-overwrap (PVC). Vacuum packaging removes the volume of the pack atmosphere to levels close to zero in a gas impermeable package. Due to the lack of oxygen in the package, metmyoglobin formation is greatly reduced. Any metmyoglobin that is formed before packaging will be converted back to deoxymyoglobin by the inherent metmyoglobin reduction activity in the product (Hood, 1980). Therefore, product that has been vacuum packaged will retain its ability to bloom or form oxymyoglobin for an extended period of time. However, in practice, intial oxygen concentrations of 100 ppm is the minimum concentration that can realistically be achieved in a commercial setting (Gill, 1996). Vacuum packaged cuts of beef have been used in retail cases, however, the dull purple color from deoxymyoglobin turns consumers away from purchasing these products (Young et al., 1988). To overcome this problem, new technology employs an oxygen permeable layer underneath an oxygen impermeable film that is removed as the product is placed in the retail case. The product will then allow oxygen to combine with myoglobin to “bloom” in the retail case. More recently, scientists are using carbon monoxide gases at very low concentration (< 1%) to bind strongly to myoglobin and form carboxymyoglobin which is a very stable cherry red color (El-Badwai et al., 1964). This can be used in conjunction with other gases in a modified atmosphere such as nitrogen and carbon dioxide. However, the carboxymyoglobin bond is very stable and the cherry red color of beef has been found to last past the microbial shelf life of beef (Kropf, 1980).

Problems arise when beef has bright cherry red color, but has a high amount of lipid oxidation. Lipid oxidation can cause a rancid off-flavor and odor in meat (Skibsted et al., 1998). Increased oxygen levels in modified atmosphere packaging have been shown to increase the rate of lipid oxidation (Zhao et al., 1994).

MAP packaging offers a number of potential advantages in terms of product integrity, quality, safety, color-life, and shelf-life. However, there are still a number of technical problems associated with MAP packaging. Hunt (2002) noted that one of the major issues facing MAP packing is the fact that all muscles do not work equally in these systems and that color stability can be the most limiting factor in case-ready MAP.

In the past few years, a new trend towards marketing individually dissected muscles has resonated throughout the industry. A complete bovine carcass muscle profiling project, funded by the National Cattlemen's Beef Association (NCBA), was completed by Jones et al. (2001) that characterized the tenderness and processing traits of each specific muscle within the carcass. A similar carcass dissection study conducted at Texas A&M University (Belew, 2000) investigated the shear value differences between individual muscles. Both studies showed that individual beef muscles are inherently different in their tenderness and processing characteristics and that they can be more effectively merchandised by marketing individual muscles and accentuating their most positive characteristics. One of the key drivers to this research initiative has been the need to identify underutilized muscles from the round and chuck. NCBA has been promoting "Beef Value Cuts" (NCBA, 2001) as a retail merchandising promotion to inform meat market managers about the merchandising opportunities that these underutilized muscles present. However, there is limited scientific data that characterizes the color stability of these muscles and determines how they will maintain their color in the retail meat case.

Researchers have identified a number of biochemical and physical factors that can affect color and color stability: oxygen consumption rate, oxygen penetration depth, metmyoglobin reductase activity, autoxidation, partial oxygen pressure, and pH. Oxygen consumption rates in beef muscle tissue affect color stability early postmortem. High oxygen consumption rates favor metmyoglobin formation very close to the surface of the tissue and are less color-stable (Ledward, 1991).

By investigating those factors that impact color stability; this information will assist retailers by improving meat case management and potentially reduce the amount of discarded and devalued product. Finally, results from this study will further facilitate the introduction and adoption of individual muscles from underutilized portions of the beef round and chuck by retailers and thus add value to the carcass.

CHAPTER III

MATERIALS AND METHODS

Phase 1. Biochemical characterization of color stability of beef muscles.

USDA Select beef subprimals were purchased from a commercial packing facility and shipped to the Rosenthal Meat Science and Technology Center at Texas A&M University. Subprimals were stored at ± 2°C until they reached 14 d of age. Table 1 shows the subprimals and muscles utilized in this study.

Table 1. Subprimals utilized and individual muscles dissected from each subprimal

NAMP 114C Beef Chuck, Shoulder Clod, trimmed	*M. Infraspinatus* (IF)
	M. Triceps brachii (TB)
	M. Teres major (TM)
NAMP 167A Beef Round, Knuckle, peeled	*M. Rectus femoris* (RF)
	M. Vastus lateralis (VL)
NAMP 169A Beef Round, Top (Inside), Cap off	*M. Semimembranosus* (SM)
NAMP 170A Beef Round, Bottom (Gooseneck), Heel out	*M. Biceps femoris* (BF)
	M. Semitendinosus (ST)
NAMP 180 Beef Loin, Strip Loin, Boneless	*M. Longissimus lumborum* (LL)
NAMP 184 Beef Loin, Top Sirloin Butt, Boneless	*M. Gluteus medius* (GM)
NAMP 189A Beef Loin, Tenderloin, Full, side muscle on, defatted	*M. Psoas major* (PM)

After aging, subprimals were separated into individual muscles and cut into 2.54 cm thick steaks by cutting perpendicular to the muscle fiber orientation. Steaks were assigned randomly to one of four packaging systems:

- Polyvinyl chloride (PVC)-Overwrap – 5 d lighted retail display
- High Oxygen MAP (80% O_2, 20% CO_2) – 4 d dark storage, 5 d lighted retail display

- Low Oxygen MAP (80% Nitrogen, 20% CO_2) – 4 d dark storage, 5 d lighted retail display
- Low Oxygen MAP (80% Nitrogen, 20% CO_2) – 9 d dark storage

and one of six display days (0-, 1-, 2-, 3-, 4-, and 5-d).

Steaks were assigned to PVC packaging and placed immediately into retail meat cases. Steaks packaged in High Oxygen MAP, and Low Oxygen MAP were stored in boxes to exclude light and simulate industry conditions for 4 d at 2°C. After 4 d, MAP packages were placed into the retail meat case. Retail meat cases were stored in a 2°C cooler to maintain a more constant temperature and minimize the effects of temperature fluctuations on meat color characteristics. After the allotted display time laboratory procedures were performed

Metmyoglobin reductase activity

Bovine heart metmyoglobin purification. Beef hearts were collected 1 d postmortem, trimmed free of fat, epicardial, and endocardial connective tissue, and were frozen at -10°C. Hearts were thawed at 4°C before metmyoglobin was extracted. Beef hearts were mixed with cold, distilled, deionized water at a ratio of 1 part beef heart to 2 parts water and homogenized in a Waring blender for 60-90 sec. The pH of the homogenate was adjusted to 7.5 using 2 N NH_4OH and centrifuged for 20 min at 13,700 × g (4°C). The supernatant was collected and brought to 70% saturation with solid $(NH_4)_2SO_4$. The pH of the supernatant was adjusted to 7.5 using 2 N NH_4OH, and the solution was allowed to stir for 30 min. After stirring, the solution was centrifuged at 13,700 × g for 15 min (4°C) and the supernatant collected. Solid $(NH_4)_2SO_4$ was added to the supernatant to bring it to 100% saturation, and the pH was adjusted to 7.5 using 2 N NH_4OH. Celite was added to the solution (1 g of Celite/ 100 mL of supernatant), and the mixture was allowed to stir for 30 min. The supernatant was vacuum-filtered through a coarse porosity glass filter and the pink filtrate was discarded. Cold water was used to elute the red oxymyoglobin from the glass filter. The oxymyoglobin solution was centrifuged at 20,000 × g for 20 min and the supernatant was collected and filtered through glass wool. The oxymyoglobin solution was oxidized to metmyoglobin using $K_3Fe(CN)_6$ and stirred for 30 min. The metmyoglobin was poured into 10,000 molecular weight cut-off dialysis tubing and dialyzed against distilled water with three periodic water changes. The metmyoglobin solution was dialyzed against 2 mM $NaPO_4$ buffer (pH 7.0) and then concentrated using Centricon filters and stored at 4°C.

A 4.45 cm diameter core was removed from each steak and the top 1/3 of each core was removed and chopped finely. Five grams of the finely chopped muscle were homogenized with 25 mL of 2 mM phosphate buffer (pH 7.0) for 45 sec in a Waring blender. The homogenate was centrifuged at 35,000 × g for 30 min (4°C) and the supernatant filtered through Whatman #541 filter paper. The supernatant was oxidized with 1-2 crystals of $K_3Fe(CN)_6$, poured into 10,000 molecular weight cut-off dialysis tubing, and dialyzed against 2 mM phosphate buffer (pH 7.0) with one phosphate buffer change-over. After dialysis, 0.2 mL of the muscle extract were placed in a micro-cuvette containing 0.1 mL of 5 mM disodium EDTA, 0.1 mL of 50 mM citrate buffer (pH 5.65), 0.1 of 3 mM potassium ferricyanide, 0.3 mL of 0.1 mM bovine metmyoglobin, and 0.1 mL distilled-deionized water. The reaction was initiated by adding 0.1 mL of 1 mM NADH. The assay was run at 30°C and absorbance measured at 580 nm. Metmyoglobin redcutase activity was calculated using the linear phase of the reaction to find the rate of change in absorbance.

Myoglobin content

Myoglobin content was determined using the muscle extract from the metmyoglobin reductase activity. Approximately 3 mL of the muscle extract was placed in a standard cuvette and absorbance was read at 572, 565, 545, and 525 nm. Myoglobin content was calculated using the equation described by Kryzwicki (1979).

Aerobic reducing activity

A 4.45 cm diameter core was removed from each steak, placed on a mini-petri dish, and wrapped with an oxygen permeable film to prevent surface dehydration. Cores were placed in a 1% oxygen/99% nitrogen environment for 24 hours. Spectral reflectance was recorded on the surface of each core immediately after removal from the low-oxygen environment. Samples were stored in the dark an additional 24 hours in a typical atmospheric environment and then spectral reflectance from the surface of each sample was recorded.

Oxygen consumption rate

Polypropylene bottles (250 mL) with modified caps were used to collect oxygen consumption data. Caps for bottles were modified by drilling a hole in the center and then septa were glued to the inside and outside of caps. Cores (4.45 cm diameter) were removed from steaks and placed in the polypropylene bottles so that the exposed surface of each core was the same surface that was exposed in the package. Bottles were flushed with oxygen, and the initial oxygen and carbon dioxide concentration in each bottle measured using a headspace analyzer (PBI Dansensor Checkpoint, PBI-Dansensor A/S, Ringted, Denmark). Bottles were stored at 4°C for 24 hr and then final oxygen and carbon dioxide concentrations measured using a headspace analyzer (PBI Dansensor Checkpoint, PBI-Dansensor A/S, Ringted, Denmark).

<u>Oxygen penetration depth</u>

To measure oxygen penetration depth, thin slices (approximately 1 cm thick) were removed from steaks at the time of cutting, by cutting perpendicular to the cut surface of steaks. Thin slices were placed immediately between two 5.1 × 5.1 cm glass plates. Ends of strips that extended outside of the glass plates were cut off. Oxygen penetration depth was measured in mm using a digital micrometer. Ten measurements were taken on each sample and averaged, and each sample was evaluated once per day.

<u>Hunter CIE L*-, a*-, and b*-values</u>

Objective color values were recorded each day. Color measurements were collected using a Hunter MiniScan XE (HunterLabs, Reston, VA) that was standardized before each use. Illuminate A, 10° standard observer, and a 3.18 cm aperature size were used when collecting values. A total of three readings were taken on each steak and averaged. CIE L* (lightness), a* (redness), and b* (yellowness) values were collected.

<u>pH</u>

The remaining portions of steaks were chopped finely. The pH of the chopped steaks was measured using a standardized handheld pH meter (pHStar, SFK

Technologies, Denmark). Two measurements were taken from each steak and averaged.

TBARS

Steaks were evaluated for lipid oxidation by measurement of 2-Thiobarbituric Acid Reactive Substances (TBARS) as described by Tarladgis et al. (1960) as modified by Rhee (1978). A 30 g sample from each steak was blended with 40-ml of double distilled water and 15 ml of propyl gallate and ethylenediaminetetracetic acid for two minutes. Thirty grams of the slurry were sprayed with 316 Silicone Release Spray lubricant (Dow Corning®, Midland, MI, USA) and transferred to distillation flasks and 2.5-ml of 4 N HCl was added to each flask. Samples were distilled until 50-ml of the distillate was collected. Two 5-ml samples were transferred from the distillate into screw cap test tubes and 5-ml of TBA reagent was added to each test tube. The test tubes were boiled for 35 min along with 2 blank test tubes, each containing 5-ml of TBA reagent and 5-ml of double-distilled water. The resulting solution was analyzed for optical reflectance at 530 nm using a spectrophotometer (Spectronic 20®, Bausch and Lomb, Rochester, NY, USA). Reflectance values were multiplied by a conversion factor of 7.8 (from the standard curve for the distillation setup in this lab) to arrive at a TBARS value. TBARS values are reported as mg of malonaldehyde per kg of sample.

Phase II. Cooked color evaluation

After the allotted number of retail display days passed, steaks were removed and evaluated for cooked color analysis. Evaluation of raw color was conducted using a three-member panel of trained color evaluators. Steaks assigned to the 5 d retail display period were evaluated for discoloration based on a 7-point scale (1 = no discoloration, 7 = 100% discoloration). Clam-shell grills (George Foreman® Model GGR62, Salton, Inc., Lake Forest, IL) were used to cook steaks to an internal temperature of 60°C. An internal temperature of 60°C was used in the study to determine premature browning effects on muscles when cooked to a rare degree of doneness. Internal temperatures were monitored using type-K thermocouples attached to Omega Trendicators. When steaks reached their endpoint cooking temperature, they were removed from grills and allowed to rest for approximately 5 min. Steaks were cut in half and the degree of doneness was determined by trained personnel using the cooked meat color guide as a reference (AMSA, 1995). Each steak half was cut open down the center of the steak, so as to maximize the exposure of internal tissue. A Hunter MiniScan was used to objectively measure internal color characteristics of each steak. Illuminate A, 10° standard observer, and a 3.18 cm aperature size were used when collecting values. A reading was taken on each quadrant within a steak and averaged. Hunter CIE L* (lightness), a* (redness), and b* (yellowness) values were collected.

Statistical analysis

Data were analyzed using the GLM procedures of SAS (SAS Institute, Cary, NC). Main effects of muscle, packaging, display time, and their interactions when appropriate were included in the model. Weight was used as a covariate in the model to analyze oxygen consumption rate. End-point temperature was placed in the model as a covariate for cooked degree of doneness and Hunter L*-, a*-, and b*- values. A significance level of $P < 0.05$ was used in all models to separate least squares means.

CHAPTER IV

RESULTS AND DISCUSSION

pH

Tables 8 thru 19 in the appendix dislplay the least squares means for pH values in different packaging environments for the 11 muscles studied. There were no major significant differences in pH among the different muscles. We expected all of the pH values to be similar so that it would not be a determining factor in color characteristics. There are some small differences between days and packaging environments but are probably due to the large number of samples in the study because there were no real trends in retail storage days or packaging environments.

TBARS

Table 2 displays the least squares means for TBARS in muscles that had significant differences. Low oxygen light was not significantly different among the 11 muscles from the low oxygen dark treatment. Lipid oxidation was used as a measure of rancidity in this study. Least squares mean values greater than one are generally considered to be rancid. The LL had no significant differences between packaging and retail storage days and all of the values were below what is considered to be rancid.

The IF, TM, RF, and BF had TBARS values in the latter storage days of high oxygen packaging that were rancid, but were not significantly different from any other packaging treatment or storage day. This trend continued with the VL, TB, ST, SM, and the GM, however, these muscles were significantly more rancid compared to the other treatments. This was probably due to the high oxygen environment allowing aerobic bacteria to grow and promote lipid oxidation compared to the low oxygen and PVC environments. These results agree with research which reported than an increase in oxygen levels in modified atmosphere packages increased lipid oxidation in meat (Zhao et al., 1994; Formanek et al., 1998). Jakobsen and Bertelsen (2000) found that to control lipid oxidation in high oxygen atmospheres, the temperature should be held less than 4^{o}C. Retailers and case-ready plants must keep temperatures low in order to protect the quality of their product.

Oxygen Penetration Depth

Least squares means for oxygen penetration depth in different packaging environments is shown in Table 3. Oxygen penetration depth was greater ($P < 0.05$) for all storage days of the high oxygen treatment in both the TB and LL. All other muscles were numerically higher but not significantly higher when compared to the other treatments because several of the oxygen penetration depths for the high oxygen treatments were completed oxygenated and there was no distinction to be made for a measurement. These data follow the logic that muscles placed in a high oxygen atmosphere will have more partial pressure of oxygen to penetrate deeper into the muscle. Gaetellier et al. (2001) are in agreement with these results and found an increase in oxygen penetration depth in the LL and TB in MAP with a high pressure of oxygen which in turn increased the shelf-life of those muscles.

Table 2. Least squares means of TBARS for packaging and shelf life day effects on the *M. Semimembranosus* (SM), *M. Gluteus medius* (GM), *M. Semitendinosus* (ST), *M. Triceps brachii* (TB), and the *M. Vastus lateralis* (VL).

Muscle	SM	GM	ST	TB	VL
HOX [a]					
0	0.67bc	0.80a	0.08cd	0.45de	0.53def
1	0.55c	0.03c	0.29bcd	0.31de	1.59ab
2	1.01b	0.28bc	0.60b	0.19e	1.27bc
3	1.07b	0.67ab	0.64b	0.32de	2.00a
4	1.07b	1.05a	0.44bc	1.45a	1.65ab
5	1.67a	0.33bc	1.39a	1.68a	1.79a
LOXDK [a]					
0	0.08d	0.24c	0.06d	0.15e	0.22fg
1	0.11d	0.07c	0.04d	0.20e	0.17fg
2	0.10d	0.19c	0.10cd	0.06e	0.21fg
3	0.06d	0.04c	0.09cd	0.10e	0.23fg
4	0.12d	0.09c	0.02d	0.23e	0.25fg
5	0.13d	0.05c	0.11cd	0.28de	0.24fg
PVC [a]					
0	0.04d	0.02c	0.03d	0.05e	0.02g
1	0.08d	0.03c	0.05d	0.10e	0.06fg
2	0.16d	0.07c	0.10cd	0.14e	0.34efg
3	0.42cd	0.15c	0.11cd	0.33de	1.01cd
4	0.30cd	0.22c	0.20cd	0.95bc	0.81cde
5	0.58c	0.22c	0.17cd	1.27ab	1.29bc

abcdefg Means within a column with a different letter differ ($P < 0.05$).
[a] HOX = High Oxygen; LOXDK = Low Oxygen dark; PVC = PVC overwrap.

Table 3. Least squares means of oxygen penetration depth for packaging and shelf life day effects on the *M. Longissimus lumborum* (LL) and *M. Triceps brachii* (TB).

Muscle	LL	TB
HOX [a]		
0	8.65a	9.97ab
1	9.18a	10.31a
2	8.56ab	9.99a
3	7.24bc	5.83c
4	6.07cde	10.68a
5	6.56cd	8.14b
LOXDK [a]		
0	3.17gh	3.59efgh
1	2.96gh	3.44efghi
2	3.14gh	3.93def
3	4.67efg	4.30de
4	4.44fg	3.68efg
5	4.21g	4.33de
PVC [a]		
0	3.79gh	2.06j
1	4.36g	4.05def
2	4.25g	5.19cd
3	4.16g	5.01cd
4	5.91cdef	5.17cd
5	4.10g	4.47cd

abcdefghi Means within a column with a different letter differ ($P < 0.05$).

[a] HOX = High Oxygen; LOXDK = Low Oxygen dark; PVC = PVC overwrap.

Metmyoglobin Reductase Activity

Appendix tables 8 thru 19 display the least squares means for metmyoglobin reductase activity. It has been theorized that an increase in metmyoglobin reductase activity will increase the ability of the muscle to rebloom or regenerate a bright cherry red color. There were significant differences between packaging environments and retail storage days but no real pattern or trends to explain the results found for all muscles. Therefore, packaging treatments and retail storage days did not affect myoglobin reductase activity.

Myoglobin Content

Myoglobin content least squares means for the TM, BF, ST, VL, and RF are displayed in Table 4. Myoglobin content was higher ($P < 0.05$) in the low oxygen dark and low oxygen light packaging treatment as compared to the high oxygen treatment for most of the retail storage days in the TM, BF, ST, VL, and RF. Myoglobin content was numerically higher in the other muscles for the low oxygen packaging treatments versus the high oxygen packaging treatments but were not significant. This may be explained by the extreme bloom caused by a high oxygen environment which will denature myoglobin more readily compared to a low oxygen environment.

Table 4. Least squares means of myoglobin content for packaging and shelf life day effects on the *M. Teres major* (TM), *M. Biceps femoris* (BF), *M. Semitendinosus* (ST), *M. Vastus lateralis* (VL), and the *M. Rectus femoris* (RF).

Muscle	TM	BF	ST	VL	RF
HOX[a]					
0	4.89defgh	5.92ijkl	3.18jkl	4.80e	4.11fg
1	5.08cdefgh	5.34kl	3.46jkl	4.59ef	3.54g
2	4.14h	7.15fghij	2.94l	4.11ef	4.75efg
3	4.19h	5.75jkl	3.75ijkl	4.14ef	4.06fg
4	4.19h	4.95l	3.66ijkl	4.32ef	4.05fg
5	4.25h	6.32ghijkl	3.04kl	3.63f	3.52g
LOXDK[a]					
0	5.81abcd	7.72efgh	5.63defg	7.94a	5.93abcd
1	5.58abcdef	7.54efghi	6.10bcde	7.65ab	5.43cde
2	5.41bcdefg	9.48bcd	5.81cdef	7.26abc	6.04abcd
3	5.66abcde	9.88bc	6.91bc	7.02abcd	5.82abcde
4	5.75abcd	9.76bc	6.78bcd	6.17d	5.97abcde
5	6.23ab	10.58b	7.17b	6.80bcd	5.06def
PVC[a]					
0	6.27ab	7.90defg	5.44efg	7.39abc	6.64abc
1	6.53a	7.38efghij	4.86fgh	6.94abcd	6.71ab
2	5.23cdefg	7.62efgh	4.34hij	6.80bcd	4.74efg
3	4.77efgh	6.09hijkl	4.52ghi	6.19d	4.86def
4	4.68fgh	6.44ghijkl	3.87ijkl	4.74e	4.90def
5	4.50gh	6.93ghijk	4.21ijk	4.70e	3.91fg

abcdefghijkl Means within a column with a different letter differ ($P < 0.05$).

[a] HOX = High Oxygen; LOXDK = Lox Oxygen Dark; PVC = PVC overwrap.

Hunter CIE L* a* and b*

Hunter CIE a* (redness) and b* (yellowness) values significantly decreased with advancing retail storage day for the high oxygen and PVC treatments across all muscles. Low oxygen light and dark environments did not affect Hunter CIE a* or b* values across retail storage days. In the initial days of retail storage, both the high oxygen and PVC treatments had higher ($P < 0.05$) values than the low oxygen treatments. However, by day 5, the SM, TM, BF, ST, and VL had a* and b* values similar to the steaks in the low oxygen environments. These values indicate the shelf life capabilities of these muscles in a high oxygen and PVC package. Hunter CIE L* (lightness) values were not as significantly affected by packaging environment or retail storage day. Figure 1 is a representation of differences in muscles and shelf life days for Hunter CIE a* values packaged in a high oxygen atmosphere. In general the BF, PM, ST, and TM decreased in Hunter CIE a* value very rapidly when when placed in a retail display case at day one and two. The LL as expected remained red for all five shelf life days as did the IF. The muscles from the beef knuckle (RF, VL), the GM and the TB did not decrease in redness until after three to four days, displaying a greater ability for color stability. Hood (1980), found that muscle type contributed to color stability with the LL being very stable and the PM very unstable, which reiterates the findings of the present research. Figure 2 illustrates the same differences in muscles across shelf life days but overwrapped with PVC. The BF and ST muscles again decreased in redness values very quickly, however, the PM remained relatively consistent throughout the five shelf life days. The LL was the most stable muscle along with the VL, RF, IF, and GM remained relatively stable in redness across all five shelf life days.

Phase II

Cooked Hunter CIE L*- a*- b*-

There were observed differences in cooked meat redness between the high oxygen environment and the low oxygen packaged steaks for the different muscles studied. Table 5 represents the least squares means values of Hunter CIE a* for the TB, ST, SM, and RF. Hunter CIE a* values were significantly lower or less red in the high oxygen environment for the TB, ST, SM, and RF than in the low oxygen dark and low oxygen light packaging treatments. The other muscles were numerically different but were not significant. There were differences between Lightness or L* Hunter values and b* or yellowness values but no major trends were detected due to shelf life day or MAP packaging environment within the cooked steaks.

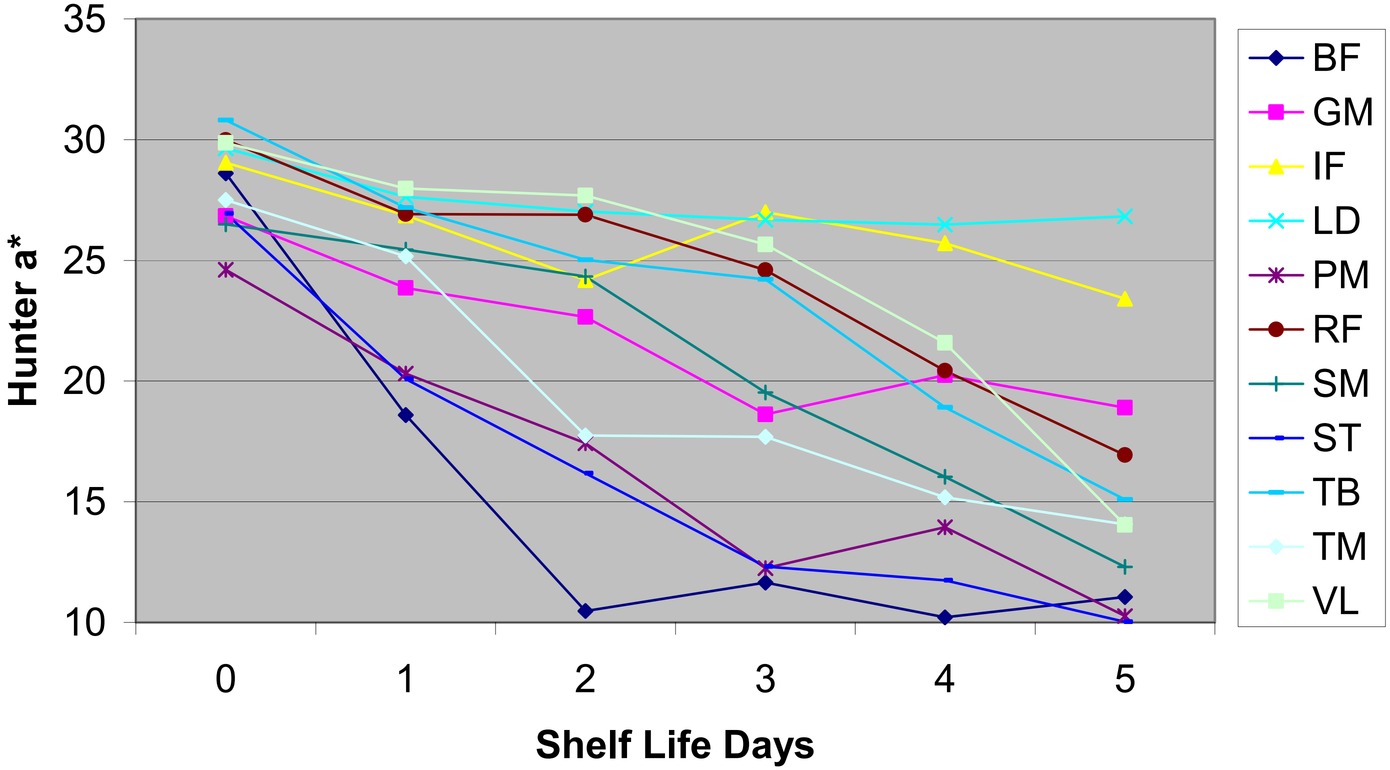

Figure 1. Differences in muscles and shelf life days in Hunter CIE a* values in a high oxygen package.

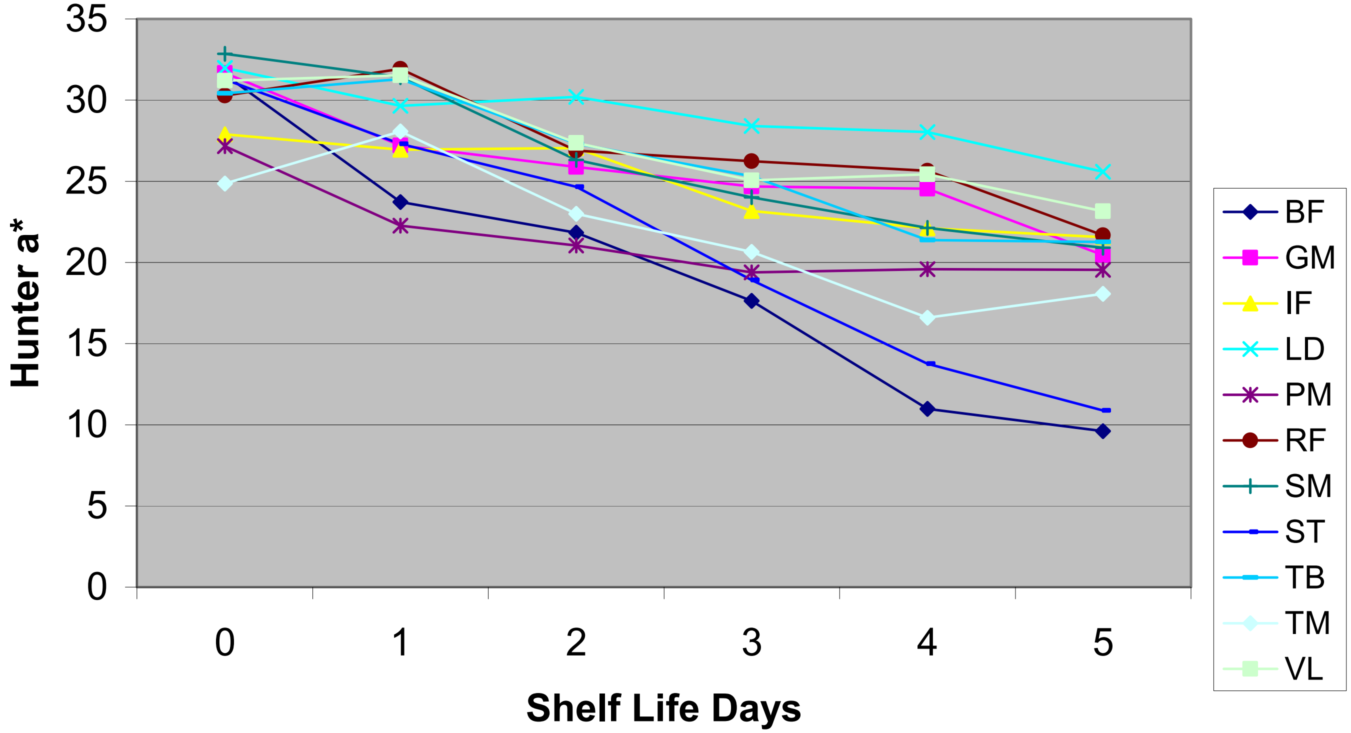

Figure 2. Differences in muscles and shelf life days in Hunter CIE a* values overwrapped in PVC.

Table 5. Least squares means of cooked Hunter CIE a* values for packaging and shelf life day effects on the *M. Triceps brachii* (TB), *M. Semitendinosus* (ST), *M. Semimembranosus* (SM) *, M. Gluteus medius* (GM)*, ,* and the *M. Rectus femoris* (RF).

Muscle	TB	ST	SM	RF
HOX[a]				
0	20.64d	10.02f	14.11g	15.56d
1	11.56e	17.57de	14.29g	14.99d
2	13.19e	15.77e	13.96g	15.81bcd
3	20.77d	13.83ef	20.49def	13.42d
4	13.00e	15.56e	16.85fg	16.22bcd
5	14.69e	15.97e	18.79ef	13.47d
LOXDK[a]				
0	27.28a	22.07bc	26.70ab	25.54a
1	25.78ab	23.81abc	26.46ab	23.81a
2	25.84ab	25.89ab	26.07abc	25.90a
3	26.26ab	23.26abc	25.62abc	23.70a
4	24.94abc	23.55abc	26.79ab	25.23a
5	26.74a	24.76abc	26.21abc	25.04a
PVC[a]				
0	25.38abc	26.83a	25.92abc	25.47a
1	24.78abcd	23.69abc	25.45abc	23.42a
2	23.16abcd	24.20abc	22.28cde	23.38a
3	26.10ab	24.76abc	24.06bcd	18.69bc
4	22.45bcd	21.05cd	25.53abc	19.17b
5	21.42cd	21.06cd	18.48ef	13.88d

abcdefg Means within a column with a different letter differ ($P < 0.05$).
[a] HOX = High Oxygen; LOXDK = Low Oxygen dark; PVC = PVC overwrap.

Discoloration

Least squares means of discoloration values for the TB, SM, VL, BF, IF, GM, PM, and TM in different packaging environments are displayed in Table 6. Discoloration significantly increased as storage days progressed in the high oxygen and PVC packages for the TB, SM, VL, BF, IF, GM, PM, and TM. Numerical increases in discoloration were similar in the RF, but were not significant, following the trend of the other muscles. These results were expected as steaks will discolor as retail display day increases. Low oxygen light and low oxygen dark packaging treatments overall were not affected by storage day which was due to their deoxymyoglobin color throughout the study.

Degree of Doneness

There were observed differences between the high oxygen modified atmosphere packages and the low oxygen modified atmosphere packages. Table 7 displays the least squares means for degree of doneness values for the PM, TB, and SM in different packaging environments. The PM, TB, and SM displayed a higher ($P < 0.05$) degree of doneness when compared to the low oxygen light and low oxygen dark packaging treatment. All other muscles had higher numerical differences for high oxygen packing versus the two low oxygen treatments but were not significant. This may be caused by the decreased myoglobin content in the raw muscle when exposed to a high oxygen environment that allows a premature browning when cooked to a rare degree of doneness internal temperature.

Table 6. Least squares means of discoloration[a] for packaging and shelf life day effects on the *M. Triceps brachii* (TB), *M. Vastus lateralis* (VL), *M. Semimembranosus* (SM), *M. Gluteus medius* (GM), and *M. Psoas major* (PM).

Muscle	TB	VL	SM	GM	PM
HOX[b]					
0	1.3h	1.0g	1.8hi	1.0j	1.1h
1	1.8h	1.1fg	2.7gh	1.3ij	1.3h
2	3.0fg	1.9efg	3.7efg	2.3hi	3.1fg
3	6.1ab	2.7def	4.8cde	3.6fg	3.3fg
4	6.3a	3.7cd	6.5ab	5.5cd	4.8cde
5	6.5a	4.3bc	6.8a	6.4abc	5.0bcd
LOXDK[b]					
0	7.0a	5.9ab	7.0a	7.0a	7.0a
1	7.0a	6.5a	7.0a	7.0a	7.0a
2	7.0a	7.0a	7.0a	7.0a	7.0a
3	7.0a	7.0a	7.0a	5.6bcd	7.0a
4	6.6a	7.0a	3.9def	4.9de	7.0a
5	4.9cd	7.0a	3.5fg	4.6def	7.0a
PVC[b]					
0	1.3h	1.0g	1.3i	1.0j	1.0h
1	1.5h	1.3fg	1.5i	1.1j	2.0gh
2	2.0gh	1.0g	2.0hi	1.3ij	3.1fg
3	3.0fg	3.1cde	4.2def	2.7gh	3.9def
4	3.5ef	3.2cde	5.1cd	3.3g	3.7ef
5	4.1de	3.6cd	5.4bc	3.9efg	4.6de

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] Score of 1=0%; 2=1-19%; 3=20-39%; 4=40-59%; 5=40-59%; 6=80-99%; 7=100%.

[b] HOX = High Oxygen; LOXDK = Low Oxygen dark; PVC = PVC overwrap.

Table 7. Least squares means of degree of doneness[a] for packaging and shelf life day effects on the *M. Triceps brachii* (TB), *M. Semimembranosus* (SM), and the *M. Psoas major* (PM).

Muscle	TB	SM	PM
HOX[b]			
0	3.0cd	4.4abcd	4.0abcd
1	5.0ab	4.8ab	3.9abcde
2	2.4de	5.0a	4.8ab
3	3.8bc	3.6cdef	4.2abc
4	5.2a	4.4abcd	4.9a
5	3.8bc	4.6abc	3.4cdefg
LOXDK[b]			
0	2.0def	1.7j	2.4fghi
1	2.4de	3.4defg	1.3ij
2	1.0f	2.0ij	3.1cdefg
3	2.0def	3.2efgh	2.8defg
4	1.8def	2.2hij	2.9cdefg
5	2.0def	2.2hij	3.1cdefg
PVC[b]			
0	2.5cde	3.2efgh	3.5bcdef
1	2.3def	3.0fghi	2.1ghij
2	2.6cd	3.8bcdef	2.1ghij
3	2.0def	3.2efgh	1.5hij
4	2.4de	3.8bcdef	3.8abcde
5	2.8cd	4.2abcde	3.3cdefg

abcdefghij Means within a column with a different letter differ ($P<0.05$).

[a] Score of 1=Very rare; 2=Rare;3=Med Rare;4=Med;5=Well done; 6=Very Well done

[b] HOX = High Oxygen; LOXDK = Low Oxygen dark; PVC = PVC overwrap.

Oxygen consumption rate

There were some significant differences in oxygen consumption rate but there were no trends in storage day or packaging treatment (see appendix tables 8-19). We previously theorized that oxygen consumption rate would decrease over storage day, however, we found no evidence to support this in our research. This may have been due to the 14 day storage prior to steak cutting which decreased differences in muscles.

Aerobic Reducing Ability

Figures 3 and 4 display least squares means for packaging environment and storage day on aerobic reducing ability of the muscles used in this study. Generally, muscles had lower aerobic reducing ability as days of retail display increased. As the percentage resistance to induced metmyoglobin formation increased, the corresponding Hunter a* value or redness typically decreased. This held true as the LL was the lowest in percentage resistance to metmyoglobin formation and had the highest or most stable color values. We expect these muscles may have used some of their aerobic reducing ability during the 4-day, dark storage period.

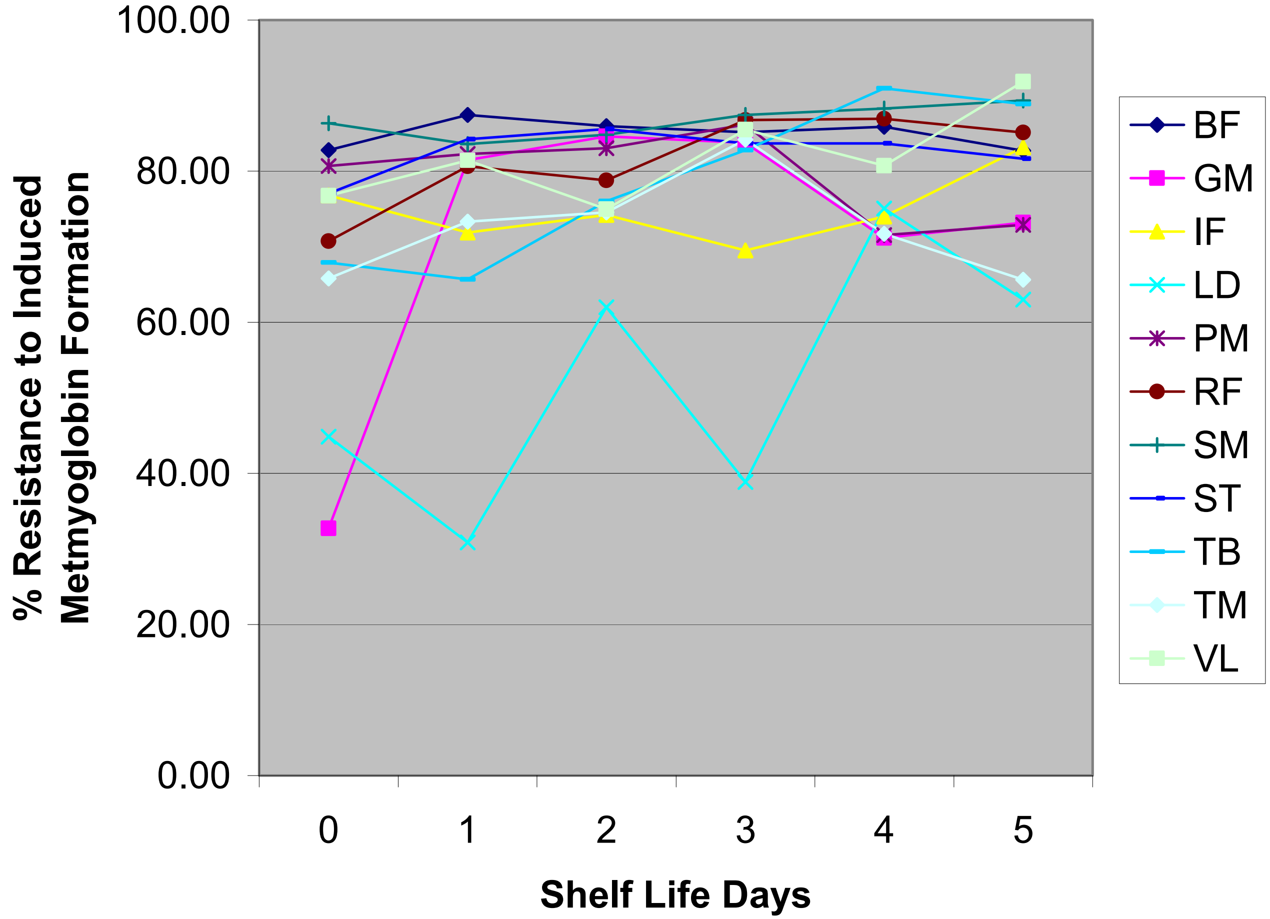

Figure 3. Differences in muscles and shelf life days in aerobic reducing ability in a high oxygen package.

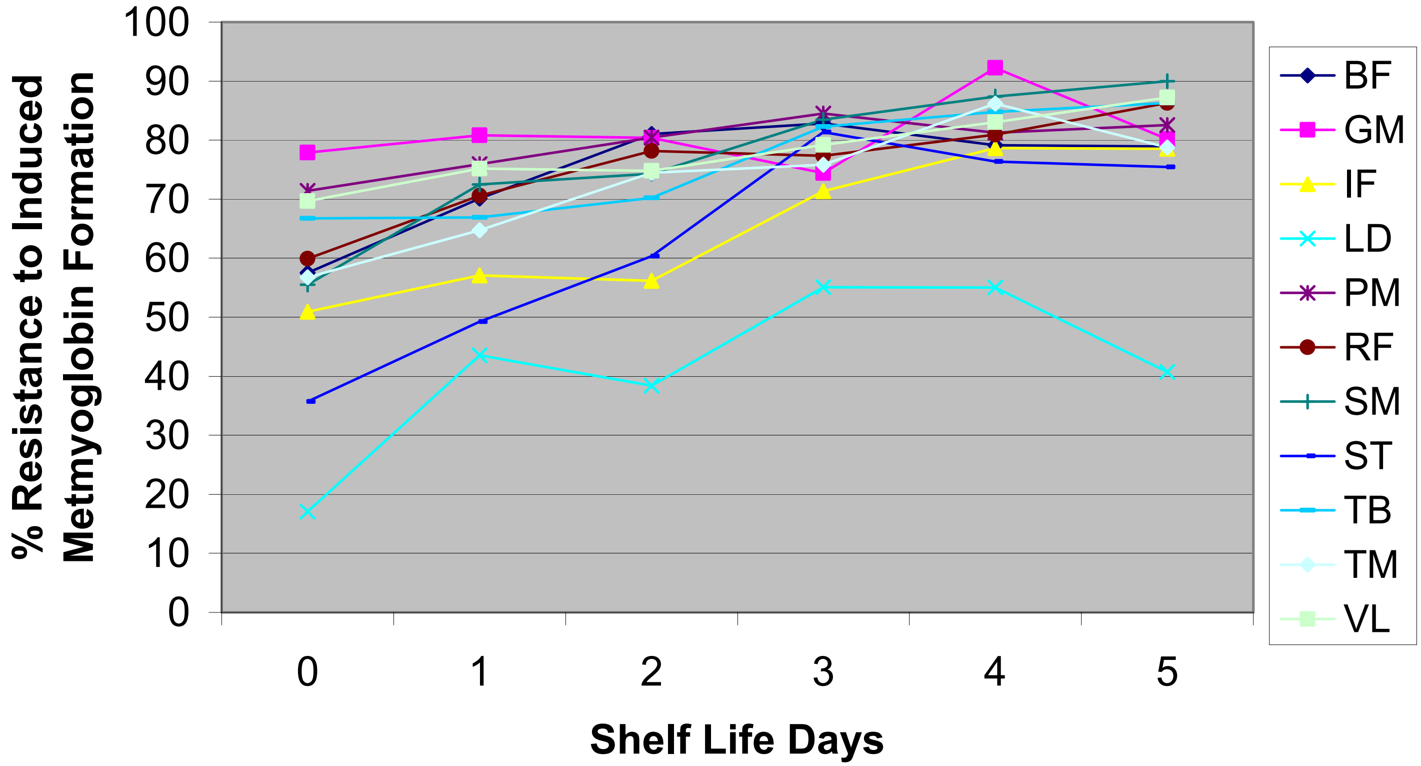

Figure 4. Differences in muscles and shelf life days in aerobic reducing ability overwrapped in PVC.

CHAPTER V

CONCLUSIONS

Color stability and cooked muscle color can be affected by several different factors. In this study, oxygen consumption rate, pH, and metmyoglobin reductase activity were not affected by packaging environment or shelf-life days overall. This was probably due to the 14 day aging period used prior to packaging. A high oxygen environment however, will increase rancidity, increase oxygen penetration depth, decrease myoglobin content, increase Hunter CIE a* values, and increase degree of doneness when compared to a low oxygen light and low oxygen dark modified atmosphere package. For Hunter CIE a* values, the LL and IF were high in color stability, the GM, RF, and TB were average, and the VL, TM, SM, PM, ST, and BF were low in color stability after five days of case-life. In a PVC overwrap environment, the LL, VL, RF, GM, IF, and TB were high in color stability, the PM and TM were average in color stability, and the ST and BF were low in color stability for five days of case-life

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APPENDIX

Table 8. Least Squares Means of pH, Oxygen Penetration Depth, Metmyoglobin Reductase Activity, Hunter CIE L* and b* values, and Oxygen Consumption Rates for Packaging and Shelf Life Day Effects on the *M. Gluteus medius.*

Trt x Day	pH	OPD[a]	MRA[b]	L*	b*	OCR[d]
HOX [e]						
0	5.62efg	12.97	0.0859cde	47.61bc	19.86bc	12.2abcde
1	5.62efg	9.57	0.0811def	49.03ab	18.54cde	13.3abcde
2	5.60fg	9.53	0.1014abc	46.79bcde	18.4cde	10.1de
3	5.74ab	6.79	0.084def	46.6bcdef	15.8f	15.7abc
4	5.69cd	7.28	0.0766def	51.75a	16.93ef	15.3abc
5	5.72ab	7.43	0.0836def	49b	17.04ef	12.5abcde
LOXDK[e]						
0	5.63ef	4.25	0.093abcd	44.8defghi	14.21g	8.7e
1	5.63ef	3.03	0.0805def	43.62ghi	12.47hij	13.0abcde
2	5.58ghij	3.4	0.0835def	45.11cdefghi	13.61ghi	12.1abcde
3	5.75a	3.49	0.0532g	45.92cdefgh	13.78ghi	10.6cde
4	5.66de	5.58	0.1085a	46.02cdefg	13.98gh	13.6abcd
5	5.76a	7.23	0.1023ab	44.64efghi	12.66ghij	16.1ab
LOXL [e]						
0	5.61fg	4.99	0.079def	45.1cdefghi	13.7ghi	9.4de
1	5.62ef	4.71	0.0892bcde	43.01i	13.1ghij	15.5abc
2	5.57hij	5.39	0.1059a	43.79ghi	13.43ghi	11.1cde
3	5.17bc	5.68	0.0763def	43.83ghi	12.16ij	10.9cde
4	5.69cd	7.62	0.0945abcd	46.06cdefg	11.73j	16.9a
5	5.76a	6.16	0.0864bcde	45.68cdefghi	12.6ghij	11.7bcde
PVC [e]						
0	5.60fghi	3.08	0.0822def	47.41bcd	23.69a	12.1abcde
1	5.54j	4.01	0.1091a	43.95fghi	20.41a	11.2bcde
2	5.60fgh	4.56	0.08def	45.49cdefghi	21ab	11.8abcde
3	5.56ij	4.31	0.0681fg	45.68cdefghi	19.37bcd	15.6abc
4	5.58ghi	5.17		43.6hi	19.39bc	9.2de
5	5.69cd	4.6	0.0738ef	45.5cdefghi	17.79de	12.7abcde

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] OPD = Oxygen penetration depth (mm.).

[b] MRA = Metmyoglobin reducing ability.

[c] Myo Cont = Myoglobin content.

[d] OCR = oxygen consumption rate of a cube (3 x 3 x 1.3 cm^3) over 24 h.

[e] HOX = High Oxygen; LOXDK = Low Oxygen Dark; LOXL = Low Oxygen Light; PVC = PVC overwrap.

Table 9. Least Squares Means of pH, Oxygen Penetration Depth, Metmyoglobin Reductase Activity, Hunter L* and b* values, and Oxygen Consumption Rates for Packaging and Shelf Life Day Effects on the *M. Infraspinatus*.						
Trt x Day	pH	OPD[a]	MRA[c]	L*	b*	OCR[d]
HOX[e]						
0	5.96cd	8.55	0.0579defgh	49.57	20.02a	13.3defgh
1	6.07ab	8.69	0.0774abc	50.67	18.43bc	14.9cdefg
2	5.99bc	9.36	0.0689abcdef	46.94	16.72d	12.6efghi
3	5.98bc	7.31	0.0408h	49.32	18.64abc	18.2bcd
4	5.95cde	9.4	0.0675abcdefg	48.54	18.34bc	27.0a
5	5.755f	9.39	0.0619cdefg	48.94	17.43cd	12.4efghi
LOXDK[e]						
0	5.99bc	3.61	0.0648cdefg	44.13	10.93e	16.4cde
1	5.99bc	2.14	0.0699abcdef	45.19	10.65e	13.4defgh
2	5.95cde	2.85	0.072abcde	46.68	10.67e	6.0k
3	5.92cde	2.91	0.0523fgh	45.21	11.43e	8.4ijk
4	5.86e	2.5	0.063cdefg	45.14	10.99e	19.0bc
5	5.71f	2.65	0.0763abcde	46.89	10.29e	11.9efghi
LOXL[e]						
0	5.96cd	2.35	0.0568efgh	45.93	10.64e	7.4jk
1	5.99bc	1.82	0.0757abcde	45.90	11.42e	10.5hij
2	5.98bc	2.49	0.066bcdefg	44.30	10.95e	11.3ghij
3	5.92cde	2.3	0.0678abcdefg	44.44	10.44e	11.4fghij
4	5.75f	2.24	0.0692abcdef	43.38	10.11e	20.8b
5	5.60g	2.39	0.0488gh	46.25	11.49e	9.1hijk
PVC[e]						
0	5.91cde	1.54	0.0846ab	44.71	19.31ab	10.8ghij
1	5.87de	3.27	0.0766abcd	44.33	19.36ab	16.0cdef
2	5.87de	3.52	0.0858a	43.69	19.92a	12.4efghi
3	5.91cde	3.77	0.0626cdefg	42.69	17.41cd	18.2bc
4	6.12a	3.41	0.0594cdefgh	42.02	17.59cd	10.6ghij
5	6.17a	3.61	0.0594cdefgh	43.60	17.67cd	12.8efghi

abcdefghij Means within a column with a different letter differ ($P < 0.05$).
[a] OPD = Oxygen penetration depth (mm.).
[b] MRA = Metmyoglobin reducing ability.
[c] Myo Cont = Myoglobin content.
[d] OCR = oxygen consumption rate of a cube ($3 \times 3 \times 1.3\ cm^3$) over 24 h.
[e] HOX = High Oxygen; LOXDK = Low Oxygen Dark; LOXL = Low Oxygen Light; PVC = PVC overwrap.

Table 10. Least Squares Means of pH, Oxygen Penetration Depth, Metmyoglobin Reductase Activity, Hunter L* and b* values, and Oxygen Consumption Rates for Packaging and Shelf Life Day Effects on the *M. Longissimus lumborum.*

Trt x Day	pH	OPD[a]	MRA[b]	L*	b*	OCR[d]
HOX						
0	5.58h	8.65a	0.0641defgh	49.61bc	22.12bc	10.9
1	5.75ab	9.18a	0.0915bc	47.63bcdefg	20.88cde	7.5
2	5.72bcde	8.56ab	0.0729cdefgh	48.53bcd	20.63de	9.2
3	5.74abc	7.24bc	0.0602efghi	47.34cdefg	19.74e	11.6
4	5.60h	6.07cde	0.0722cdefgh	49.73b	21.1cde	14.8
5	5.72bcde	6.56cd	0.0692cdefgh	47.72bcdefg	21.01cde	15.5
LOXDK						
0	5.61h	3.17gh	0.0354i	46.36defg	12.2hi	14.4
1	5.76ab	2.96gh	0.0763cdefg	45.63fgh	12.97ghi	9.5
2	5.71cde	3.14gh	0.0622efgh	49.81b	14.43f	15.0
3	5.72abcd	4.67efg	0.0837bcde	43.68h	11.6i	9.6
4	5.70efg	4.44fg	0.0759cdefg	48.84bc	13.03gh	10.7
5	5.70efg	4.21g	0.0705cdefgh	46.25defg	13.64fgh	17.3
LOXL						
0	5.59h	2.28h	0.0727cdefgh	45.52gh	13.04fgh	14.8
1	5.73abc	3.34gh	0.0522ghi	53.64a	13.55fgh	16.7
2	5.70def	2.68gh	0.0797bcdef	45.99efgh	14.21fg	16.1
3	5.72abcde	4.39fg	0.0866bcd	46.06efg	12.92ghi	11.8
4	5.67g	4.42fg	0.0627defgh	47.9bcdef	13.53fgh	14.3
5	5.68fg	4.73defg	0.0728cdefgh	47.3cdefg	14.02fg	12.8
PVC						
0	5.62h	3.79gh		45.77efgh	23.89a	13.3
1	5.55h	4.36g	0.1304a	48.01bcde	22.02bcd	9.1
2	5.58h	4.25g	0.1034b	47.33cdefg	22.73ab	12.4
3	5.61h	4.16g	0.0579fghi	45.96efgh	21.46bcd	13.3
4	5.57h	5.91cdef	0.0634defgh	46.48defg	21.83bcd	9.5
5	5.75a	4.10g	0.0508hi	46.55defg	20.68de	14.4

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] OPD = Oxygen penetration depth (mm.).

[b] MRA = Metmyoglobin reducing ability.

[c] Myo Cont = Myoglobin content.

[d] OCR = oxygen consumption rate of a cube ($3 \times 3 \times 1.3$ cm^3) over 24 h.

[e] HOX = High Oxygen; LOXDK = Low Oxygen Dark; LOXL = Low Oxygen Light; PVC = PVC overwrap.

Table 11. Least Squares Means of pH, Oxygen Penetration Depth, Metmyoglobin Reductase Activity, Hunter L*and b* values, and Oxygen Consumption Rates for Packaging and Shelf Life Day Effects on the *M. Rectus femoris.*

Trt x Day	pH	OPD[a]	MRA[b]	L*	b*	OCR[d]
HOX[e]						
0	5.92a	9.37	0.0306	52.53	22.8ab	10.9cdef
1	5.90a	10.5	0.0416	52.17	20.26de	8.7f
2	5.86ab	9.78	0.0365	49.39	19.79de	9.6def
3	5.75hij	10.36	0.0335	50.76	18.95e	13.5bcd
4	5.74hij	7.75	0.0310	50.71	17.28f	8.1f
5	5.76fghij	9.19	0.0324	50.62	16.14fg	12.9cde
LOXDK[e]						
0	5.92a	2.43	0.0397	48.60	14.24hi	10.9cdef
1	5.83bcd	2.66	0.0415	49.76	14.42hi	8.9ef
2	5.80cdefg	3.03	0.0299	50.28	14.58gh	8.5f
3	5.73ij	3.45	0.0293	48.70	13.46hij	11.7cdef
4	5.77efghij	2.92	0.0302	47.59	13.09hij	9.1def
5	5.74hij	3.4	0.0241	48.01	13.93hi	13.1cde
LOXL[e]						
0	5.85bc	1.98	0.0371	49.86	13.55hij	10.6cdef
1	5.92a	2.28	0.0432	48.68	13.19hij	8.8ef
2	5.81bcdef	2.63	0.0517	49.73	13.78hij	9.7def
3	5.77efghij	2.58	0.0341	46.63	12.22j	17.7b
4	5.72j	2.28	0.0313	48.80	13.64hij	11.1cdef
5	5.75hij	2.82	0.0314	47.35	12.9ij	14.3bc
PVC[e]						
0	5.82bcde	3.8	0.0491	49.36	22.05bc	10.9cdef
1	5.78efghi	5.21	0.0310	48.03	23.86a	12.3cdef
2	5.80cdefgh	5.27	0.0379	47.1	21.3bcd	29.4a
3	5.79defgh	5.97	0.0398	48.01	20.83cd	10.7cdef
4	5.75ghij	5.55	0.0353	47.20	19.89de	14.4bc
5	5.77efghij	5.25	0.0394	49.10	20.04de	3.4g

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] OPD = Oxygen penetration depth (mm.).

[b] MRA = Metmyoglobin reducing ability.

[c] Myo Cont = Myoglobin content.

[d] OCR = oxygen consumption rate of a cube (3 x 3 x 1.3 cm^3) over 24 h.

[e] HOX = High Oxygen; LOXDK = Low Oxygen Dark; LOXL = Low Oxygen Light; PVC = PVC overwrap.

Table 12. Least Squares Means of pH, Oxygen Penetration Depth, Metmyoglobin Reductase Activity, Hunter CIE L* and b* values, and Oxygen Consumption Rates for Packaging and Shelf Life Day Effects on the *M. Semimembranosus.*

Trt x Day	pH	OPD[a]	MRA[b]	L*	b*	OCR[d]
HOX[e]						
0	5.71efghi	6.47	0.0811ab	49.18a	21.56b	8.6ef
1	5.69ghi	7.82	0.0714bcdef	45.87bcdefg	20.91bc	13.7abcd
2	5.85a	7.32	0.0713bcdef	46.62abcde	20.84bc	13.2abcde
3	5.79bc	6.45	0.0655cdefgh	47.94ab	18.59de	15.2ab
4	5.81ab	7.9	0.0501j	47.66abc	17.36ef	9.9cdef
5	5.78bcd	6.58	0.0568ghij	48.21ab	16.87f	11.0bcdef
LOXDK[e]						
0	5.67i	2.95	0.0705bcdef	45.61bcdefgh	15.03g	16.2a
1	5.70efghi	3.2	0.0785abc	44.57defgh	15.02g	10.6bcdef
2	5.81ab	1.89	0.0631defghij	45.56bcdefgh	14.71g	11.7abcdef
3	5.81ab	2.82	0.0645defghi	42.66h	14.44g	12.9abcdef
4	5.82ab	3.88	0.0692bcdefg	45.36bcdefgh	14.07g	11.1bcdef
5	5.79bcd	3.65	0.0558hij	46.55abcdef	14.15g	16.4a
LOXL[e]						
0	5.71efghi	2.76	0.073bcde	45.64bcdefgh	14.76g	15.2ab
1	5.73efg	3.14	0.0642defghi	43.33gh	13.76g	12.1abcdef
2	5.85a	2.03	0.0739bcde	44.52defgh	14.57g	11.2bcdef
3	5.74def	2.94	0.0609efghij	43.62fgh	13.77g	13.4abcd
4	5.78bcd	3.73	0.0694bcdefg	46.29abcdef	14.49g	10.8bcdef
5	5.72efgh	4.13	0.0587fghij	44.16defgh	13.71g	15.0ab
PVC[e]						
0	5.74cde	3.21	0.089a	43.72efgh	24.91a	12.6abcdef
1	5.75cde	5.61	0.0515ij	47.14abcd	23.65a	8.5f
2	5.71efghi	4.84	0.0888a	48.36ab	20.64bc	16.3a
3	5.69fghi	4.26	0.0707bcdef	43.89efgh	19.85cd	9.0def
4	5.69hi	4.42	0.0738bcde	43.92efgh	18.56de	9.4def
5	5.72efghi	4.01	0.0749bcd	44.84cdefgh	18.39de	14.6abc

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] OPD = Oxygen penetration depth (mm.).

[b] MRA = Metmyoglobin reducing ability.

[c] Myo Cont = Myoglobin content.

[d] OCR = oxygen consumption rate of a cube (3 x 3 x 1.3 cm^3) over 24 h.

[e] HOX = High Oxygen; LOXDK = Low Oxygen Dark; LOXL = Low Oxygen Light; PVC = PVC overwrap.

Table 13. Least Squares Means of pH, Oxygen Penetration Depth, Metmyoglobin Reductase Activity, Hunter L* b* values, and Oxygen Consumption Rates for Packaging and Shelf Life Day Effects on the *M. Semitendinosus.*

Trt x Day	pH	OPD[a]	MRA[b]	L*	b*	OCR[d]
HOX[e]						
0	5.62ghij	6.14	0.0498defg	54.1a	23.13a	10.3bcde
1	5.85ab	7.05	0.0731a	49.66efghi	19.97bc	10.2bcde
2	5.77d	5.48	0.0461efgh	52.83ab	18.59de	14.5ab
3	5.60hij	8.69	0.0469efgh	51.1bcde	18.31ef	8.1de
4	5.74ij	8.81	0.0599abcde	50.89cde	17.95ef	13.6bc
5	5.55j	7.23	0.049defgh	52.82abc	18ef	7.8de
LOXDK[e]						
0	5.64fghi	2.3	0.0461efgh	47.57jkl	14.59ij	9.6cde
1	5.87a	3.79	0.0697abc	46.68l	15.61hij	7.1de
2	5.79bc	3.32	0.0562abcdef	47.73ijkl	17.08fg	11.6bcde
3	5.61ghij	4.8	0.0659abcd	48.77fghijk	15.76hi	9.5cde
4	5.601hij	4.91	0.0366gh	47.4kl	16.09gh	13.1bc
5	5.61ghij	4.85	0.0321h	49.75efgh	16.14gh	8.3de
LOXL[e]						
0	5.61ghij	2.37	0.0512defg	48.74ghijk	16.12gh	7.0e
1	5.85ab	2.87	0.0569abcdef	48.79fghijk	14.41j	10.8bcde
2	5.77cd	2.7	0.0569abcdef	48.04hijkl	15.7hij	10.1cde
3	5.60hij	3.08	0.0711ab	49.53efghij	15.19hij	8.1de
4	5.77ij	3.1	0.0451efgh	48.49hijkl	15.2hij	10.8bcde
5	5.77d	3.54	0.0425fgh	48.11hijkl	14.61ij	18.1a
PVC[e]						
0	5.66fg	4.04	0.0541bcdefg	50.74def	23.78a	8.1de
1	5.68ef	4.64	0.0536bcdefg	51.88bcd	21.25b	10.2cde
2	5.74d	3.23	0.0568abcdef	50.58defg	19.85cd	7.5de
3	5.65fgh	3.42	0.0591abcdef	49.86efgh	18.06ef	13.9abc
4	5.72de	5.82	0.0528cdefg	50.77de	16.49gh	12.0bcd
5	5.92a	5.56	0.0603abcde	49.36efghijk	15.77ghi	13.6bc

abcdefghij Means within a column with a different letter differ ($P < 0.05$).
[a] OPD = Oxygen penetration depth (mm.).
[b] MRA = Metmyoglobin reducing ability.
[c] Myo Cont = Myoglobin content.
[d] OCR = oxygen consumption rate of a cube (3 x 3 x 1.3 cm^3) over 24 h.
[e] HOX = High Oxygen; LOXDK = Low Oxygen Dark; LOXL = Low Oxygen Light; PVC = PVC overwrap.

Table 14. Least Squares Means of pH, Oxygen Penetration Depth, Metmyoglobin Reductase Activity, , Hunter CIE L* b* values, and Oxygen Consumption Rates for Packaging and Shelf Life Day Effects on the *M. Teres major.*

Trt	pH	OPD[a]	MRA[b]	L*	b*	OCR[d]
HOX[e]						
0	5.85	7.06	0.0723	51.23a	19.8a	10.3def
1	5.86	6.67	0.059	49.56abcd	17.91b	6.9f
2	5.86	6.65	0.0733	48.97abcdef	15.25def	16.5ab
3	5.73	7.93	0.0552	50.18ab	15.15ef	14.6abcd
4	5.7	7.44	0.0811	49.03abcde	13.91fg	13.1bcde
5	5.77	8.4	0.0561	49.47abcd	13.59g	11.4cdef
LOXDK[e]						
0	5.75	4.52	0.0690	46.39fghi	11.38ijk	13.0bcde
1	5.85	4.66	0.0630	48.07bcdef	10.6k	18.7a
2	5.72	3.49	0.0549	47.27cdefgh	10.79jk	10.8def
3	5.66	4.7	0.0436	49.35abcd	11.48ijk	15.2abc
4	5.62	4.84	0.0597	49.62abc	12.22hi	12.9bcde
5	5.53	5.44	0.0618	49.03abcde	12.04hij	14.6abcd
LOXL[e]						
0	5.80	3.4	0.0667	49.49abcd	12hij	7.5ef
1	5.88	3.01	0.0637	46.49fghi	10.55k	11.4cdef
2	5.75	1.5	0.0615	48.42bcdef	13.2gh	14.7abcd
3	5.73	2.96	0.0529	46.61efghi	10.78jk	14.8abcd
4	5.68	3.69	0.0519	46.42fghi	10.39k	14.1abcd
5	5.68	4.25	0.0501	47.12cdefgh	11.63ijk	17.3ab
PVC[e]						
0	5.89	3.11	0.0777	47.15cdefgh	17.24bc	11.1cdef
1	5.96	4.17	0.0551	47.1defgh	20.27a	11.2cdef
2	5.92	4.08	0.0614	47.44cdefg	17.16bc	14.2abcd
3	5.91	4.33	0.0688	45.24ghi	16.61bcd	11.6cdef
4	5.88	3.05	0.0718	44.09i	15.34de	10.9cdef
5	5.93	4.21	0.0730	44.79hi	16.02cde	11.1cdef

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] OPD = Oxygen penetration depth (mm.).

[b] MRA = Metmyoglobin reducing ability.

[c] Myo Cont = Myoglobin content.

[d] OCR = oxygen consumption rate of a cube ($3 \times 3 \times 1.3$ cm^3) over 24 h.

[e] HOX = High Oxygen; LOXDK = Low Oxygen Dark; LOXL = Low Oxygen Light; PVC = PVC overwrap.

Table 15. Least Squares Means of pH, Oxygen Penetration Depth, Metmyoglobin Reductase Activity, Hunter L* and b* values, and Oxygen Consumption Rates for Packaging and Shelf Life Day Effects on the *M. Triceps brachii.*

Trt	pH	OPD[a]	MRA[b]	L*	b*	OCR[d]
HOX[e]						
0	5.70bcd	9.97ab	0.0615	49.04a	22.48b	17.6a
1	5.68bcdefg	10.31a	0.0529	46.83b	20.5c	12.5bcde
2	5.68bcdefg	9.99a	0.0607	45.59bcd	18.92d	6.3g
3	5.65efg	5.83c	0.0589	44.42cdef	18.43d	6.2g
4	5.72bc	10.68a	0.0500	45.91bc	16.11e	12.8bcd
5	5.72b	8.14b	0.0562	45.03bcdef	16.23e	9.3defg
LOXDK[e]						
0	5.73ab	3.59efgh	0.0804	43.73defghij	13.15fgh	19.9a
1	5.64fg	3.44efghi	0.0479	44.41cdefg	14.42f	11.5cdef
2	5.65efg	3.93def	0.0697	43.7defghij	14.26f	7.6fg
3	5.66defg	4.3de	0.0407	43.12fghij	13.45fgh	11.7cdef
4	5.68bcdef	3.68efg	0.0434	43.96defghi	12.98gh	11.7cdef
5	5.68bcdefg	4.33de	0.0579	43.68defghij	13.33fgh	8.1efg
LOXL[e]						
0	5.71bcd	2.29hij	0.0642	43.81defghi	14.15fg	10.7defg
1	5.67cdefg	2.21hij	0.0574	43.46efghij	13.6fgh	13.0bcd
2	5.68bcdefg	2.74fghij	0.0496	43.67defghij	13.89fgh	10defg
3	5.64g	2.14ij	0.0575	42.31hijk	12.76h	10.9defg
4	5.70bcd	2.75ghij	0.0507	43.45efghij	13.19fgh	11.4cdef
5	5.68bcdefg	2.33hij	0.0451	45.14bcde	14.24fg	12.6bcde
PVC[e]						
0	5.70bcde	2.06j	0.0782	44.16cdefgh	21.55bc	16.4ab
1	5.72bc	4.05def	0.0569	44.18cdefgh	24.01a	15.6abc
2	5.72bc	5.19cd	0.0683	42.48ghijk	21.12c	10.9defg
3	5.70bcd	5.01cd	0.0669	42.04ijk	20.39c	10.4defg
4	5.91a	5.17cd	0.0579	41.86jk	18.45d	11.2cdef
5	5.91a	4.47cd	0.0893	41.07k	18.9d	8.9defg

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] OPD = Oxygen penetration depth (mm.).

[b] MRA = Metmyoglobin reducing ability.

[c] Myo Cont = Myoglobin content.

[d] OCR = oxygen consumption rate of a cube ($3 \times 3 \times 1.3$ cm^3) over 24 h.

[e] HOX = High Oxygen; LOXDK = Low Oxygen Dark; LOXL = Low Oxygen Light; PVC = PVC overwrap.

Table 16. Least Squares Means of pH, Oxygen Penetration Depth, Metmyoglobin Reductase Activity, Hunter L* and b* values, and Oxygen Consumption Rates for Packaging and Shelf Life Day Effects on the *M. Vastus lateralis.*

Trt	pH	OPD[a]	MRA[b]	L*	b*	OCR[d]
HOX[e]						
0	5.78cdef	8.91	0.0521	48.8a	22.08ab	10.4defghi
1	5.76cdefgh	8.16	0.0463	47.23ab	20.99bc	9.3fghi
2	5.76bcdef	7.7	0.0365	46.31bcde	21.01bc	…
3	5.78cdef	9.31	0.0404	46.56abcd	19.9cd	11.9defgh
4	5.74fgh	8.61	0.0358	46.74abc	17.14e	12.5cdefg
5	5.77cdefg	7.88	0.0366	46.18bcdef	15.48f	12.1defg
LOXDK[e]						
0	5.77cdefg	2.6	0.0341	41.99ijkl	12.96hi	9.7efghi
1	5.84ab	2.86	0.0575	41.74jkl	12.56hi	9.1fghi
2	5.78cdef	3.68	0.0222	42.74hijk	13.17hi	…
3	5.79bcde	3.64	0.0414	45.21bcdefg	14.06fgh	13.2cdef
4	5.75efgh	3.07	0.0491	44.53cdefgh	13.95gh	6.3i
5	5.76cdefgh	3.55	0.0449	43.53ghijk	12.05i	11.6defgh
LOXL[e]						
0	5.81abc	2.58	0.1248	44.01fghi	14.72fg	16.9bc
1	5.82ab	2.58	0.0453	44.43defgh	13.36ghi	12.4cdefg
2	5.79bcdef	3.06	0.0352	43.03ghijk	12.39i	…
3	5.77cdefg	2.96	0.0493	44.02fghi	12.64hi	15bcd
4	5.75defgh	2.59	0.0415	43.73ghijk	12.64hi	8.6fghi
5	5.86a	2.87	0.0375	41.66kl	12.35i	19.2b
PVC[e]						
0	5.75defgh	3.2	0.0636	46.31bcde	21.96ab	14.3cde
1	5.79bcdef	4.02	0.0482	46.43bcd	23.4a	13.5cdef
2	5.81abcd	3.62	0.0545	40.16l	20.91bc	29.6a
3	5.76cdefgh	4.07	0.0538	43.95ghij	20.21cd	7.1hi
4	5.72gh	4.09	0.0439	46.73abc	20.14cd	12.7cdefg
5	5.71h	4.47	0.0350	44.09efghi	19.26d	8.4ghi

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] OPD = Oxygen penetration depth (mm.).

[b] MRA = Metmyoglobin reducing ability.

[c] Myo Cont = Myoglobin content.

[d] OCR = oxygen consumption rate of a cube (3 x 3 x 1.3 cm^3) over 24 h.

[e] HOX = High Oxygen; LOXDK = Low Oxygen Dark; LOXL = Low Oxygen Light; PVC = PVC overwrap.

Table 17. Least Squares Means of pH, Oxygen Penetration Depth, Metmyoglobin Reductase Activity, Hunter CIE L* and b* values, and Oxygen Consumption Rates for Packaging and Shelf Life Day Effects on the *M. Biceps femoris.*

Trt	pH	OPD[a]	MRA[b]	L*	b*	OCR[d]
HOX[e]						
0	5.69b	6.74	0.0768bcde	46.05	21.86a	10.0
1	5.68b	7.59	0.1077a	44.18	17.17bc	12.5
2	5.63c	8.17	0.0684cde	45.57	16.05cd	8.9
3	5.64c	8.11	0.0858abc	46.21	15.33de	9.4
4	5.55c	9.08	0.0576de	44.95	14.91defg	13.9
5	5.65c	8.69	0.0556de	45.51	16.93bc	10.3
LOXDK[e]						
0	5.70b	1.79	0.0926abc	44.09	13.69ghi	11.2
1	5.72ab	2.96	0.1067a	43.06	14.24efgh	8.6
2	5.64c	2.88	0.0838abcd	43.15	14.23efgh	11.9
3	5.65c	3.81	0.1014ab	41.51	14.01fgh	9.2
4	5.64c	4.26	0.0532e	43.80	15.17def	11.6
5	5.67bc	3.86	0.0763bcde	43.77	14.29efgh	11.5
LOXL[e]						
0	5.70b	1.62	0.0771bcde	43.35	13.33hi	9.3
1	5.71b	2.26	0.1077a	42.35	12.47i	9.6
2	5.63c	2.09	0.0765bcde	42.01	13.29hi	10.5
3	5.62d	2.98	0.0884abc	41.90	13.85gh	10.7
4	5.60d	3.42	0.1075a	42.42	14.34efgh	13.4
5	5.45e	3.41	0.0541e	42.99	13.8gh	5.0
PVC[e]						
0	5.71b	2.87	0.0762bcde	46.30	22.86a	14.4
1	5.71b	3.12	0.0785abcde	45.85	18b	10.3
2	5.72ab	2.69	0.0943abc	42.91	17.63b	12.0
3	5.70b	3.48	0.0983ab	42.22	16.9bc	9.3
4	5.72ab	5.43	0.0691cde	44.25	15.34de	11.7
5	5.76a	3.88	0.0902abc	44.79	14.23efgh	11.9

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] OPD = Oxygen penetration depth (mm.).

[b] MRA = Metmyoglobin reducing ability.

[c] Myo Cont = Myoglobin content.

[d] OCR = oxygen consumption rate of a cube (3 x 3 x 1.3 cm^3) over 24 h.

[e] HOX = High Oxygen; LOXDK = Low Oxygen Dark; LOXL = Low Oxygen Light; PVC = PVC overwrap.

Table 18. Least Squares Means of pH, Oxygen Penetration Depth, Metmyoglobin Reductase Activity, , Hunter L* and b* values, and Oxygen Consumption Rates for Packaging and Shelf Life Day Effects on the *M. Psoas major.*

Trt	pH	OPD[a]	MRA[b]	L*	b*	OCR[d]
HOX[e]						
0	5.92abcd	10.47	0.0866bcd	47.4bcdefg	24.61b	11.1
1	5.88cdef	9.26	0.0664efg	48.31abcd	20.31cd	10.7
2	5.90bcde	7.99	0.0908bc	48.78abc	17.43ef	11.6
3	5.77jhi	9.16	0.0877bcd	48.39abcd	12.25ghij	9.8
4	5.84efgj	7.43	0.0707defg	49.4ab	13.94g	15.1
5	5.79defg	11.83	0.0868bcd	47.74bcdef	10.27j	9.9
LOXDK[e]						
0	5.93abc	5.3	0.0838bcde	44.98i	12.4ghij	10.9
1	5.97a	4.91	0.0959bc	47.59bcdef	11.78ghij	13.4
2	5.86defg	5.32	0.116a	46.11fghi	11.82ghij	12.8
3	5.76hi	6.3	0.0576g	46.88cdefghi	10.86ij	13.8
4	5.76i	5.68	0.0894bcd	49.09ab	11.14ij	17.1
5	5.77hi	6.75	0.0917bc	47.5bcdef	11.6hij	12.6
LOXL[e]						
0	5.94abc	5.19	0.0824bcdef	46.87cdefghi	13.02ghi	11.1
1	5.95ab	5.51	0.0639fg	47.45bcdef	12.89ghi	12.7
2	5.92abcde	5.67	0.0968ab	47.07cdefgh	11.59hij	10.1
3	5.76hi	6.47	0.0825bcdef	46.28efghi	12.23ghij	15.6
4	5.78jhi	4.96	0.0752cdefg	48.65abcd	13.72gh	15.9
5	5.89bcde	5.48	0.0805bcdef	45.46ghi	16.76f	13.2
PVC[e]						
0	5.78jhi	2.57	0.0858bcd	48.06abcde	27.16a	10.5
1	5.81fgjh	2.51	0.116a	45.32hi	22.26c	7.5
2	5.76hi	3.75	0.0707defg	46.79defghi	21.05cd	12.8
3	5.77hi	4.43	0.0786bcdef	44.96i	19.39de	9.1
4	5.79jhi	5.54	0.0895bcd	45.95fghi	19.59de	10.1
5	5.80gjhi	4.45	0.0704defg	49.74a	19.55de	10.0

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] OPD = Oxygen penetration depth (mm.).

[b] MRA = Metmyoglobin reducing ability.

[c] Myo Cont = Myoglobin content.

[d] OCR = oxygen consumption rate of a cube (3 x 3 x 1.3 cm^3) over 24 h.

[e] HOX = High Oxygen; LOXDK = Low Oxygen Dark; LOXL = Low Oxygen Light; PVC = PVC overwrap.

Table 19. Least Squares Means of Cooked Hunter L* a* b* values, Discoloration, and Degree of Doneness for Packaging and Shelf Life Day Effects on *M. Vastus lateralis*.					
Trt	**L***	**a***	**b***	**Discolor[a]**	**Degree of Doneness[b]**
HOX					
0	52.09	18.36	17.15cdefg	1.0g	3.39
1	53.10	13.18	15.05gh	1.1fg	4.59
2	52.05	13.75	15.55fgh	1.9efg	4.59
3	51.94	15.66	17.27bcdefg	2.7def	5.00
4	55.66	15.02	15.94efgh	3.7cd	4.59
5	55.31	12.55	15.6efgh	4.3bc	5.01
LOXDK					
0	56.83	24.51	18.73abcd	5.9ab	2.39
1	53.26	26.48	19.29abc	6.5a	3.00
2	54.59	26.46	19.55a	7.0a	3.81
3	55.25	26.49	19.47ab	7.0a	2.99
4	54.36	23.67	17.71abcdef	7.0a	3.40
5	54.53	26.92	19.22abcd	7.0a	3.00
LOXL					
0	55.43	25.51	19.57a	3.1cde	2.41
1	53.17	25.70	17.86abcde	3.1cde	2.59
2	51.94	26.22	18.05abcd	3.1cde	2.84
3	47.46	22.84	13.82h	2.6defg	1.59
4	56.69	25.23	19.46ab	2.6defg	3.40
5	52.79	27.04	18.28abcd	2.5defg	3.00
PVC					
0	56.30	25.46	19.44ab	1.0g	2.99
1	52.84	24.22	17.01defg	1.3fg	1.79
2	56.90	24.67	19.39abc	1.0g	3.19
3	49.47	24.79	18.12abcd	3.1cde	1.99
4	54.24	21.32	18.28abcd	3.2cde	3.45
5	52.48	23.05	17.71abcdef	3.6cd	3.61

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] Score of 1=No discoloration; 2= Slight discoloration 1-19%; 3= Small discoloration 20-39%; 4=Modest discoloration 40-59%; 5=Moderate discoloration 40-59%; 6=Extensive discoloration 80-99%; 7=Total discoloration 100%.

[b] Score of 1=Very rare; 2= Rare; 3= Medium Rare; 4=Medium; 5=Well done; 6= Very well done.

Table 20. Least Squares Means of Cooked Hunter L* a* b* values, Discoloration, and Degree of Doneness for Packaging and Shelf Life Day Effects on *M. Biceps femoris.*

Trt	**L***	**a***	**b***	**Discolor**[a]	**Degree of Doneness**[b]
HOX					
0	48.87cdefg	22.82	17.53	--------	3.60
1	51.46abcdef	18.62	16.48	--------	4.62
2	52.05abcde	16.62	16.31	--------	4.60
3	50.67abcdef	17.72	15.96	--------	3.37
4	50.55abcdef	18.71	15.55	5.1c	3.02
5	49.7bcdefg	19.20	16.71	5.5bc	3.81
LOXDK					
0	46.62fg	26.42	18.13	------	2.41
1	52.54abc	25.40	19.67	------	3.22
2	52.47abcd	24.95	17.42	------	2.02
3	52.5abc	24.28	17.89	------	2.59
4	54.27ab	27.11	20.12	6.2ab	2.38
5	54.9a	24.87	19.52	3.4d	2.60
LOXL					
0	52.7abc	26.09	19.12	------	3.01
1	53.37abc	26.60	20.70	------	2.73
2	54.53ab	26.23	19.80	------	3.42
3	52.94abc	25.46	18.48	------	2.22
4	53.79abc	21.75	16.32	7.0a	1.82
5	55.5a	23.34	17.67	6.3ab	2.80
PVC					
0	53.15abc	26.67	18.91	1.7e	2.76
1	51.4abcdef	24.04	19.13	2.5e	3.56
2	52.68abc	26.75	20.51	3.7d	3.18
3	47.45efg	26.06	18.86	6.3ab	3.81
4	47.5defg	27.05	19.73	6.3ab	3.21
5	45.1g	26.83	18.38	6.5a	3.22

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] Score of 1=No discoloration; 2= Slight discoloration 1-19%; 3= Small discoloration 20-39%; 4=Modest discoloration 40-59%; 5=Moderate discoloration 40-59%; 6=Extensive discoloration 80-99%; 7=Total discoloration 100%.

[b] Score of 1=Very rare; 2= Rare; 3= Medium Rare; 4=Medium; 5=Well done; 6= Very well done.

Table 21. Least Squares Means of Cooked Hunter L* a* b* values, Discoloration, and Degree of Doneness for Packaging and Shelf Life Day Effects on *M. Gluteus medius.*

Trt	L*	a*	b*	Discolor[a]	Degree of Doneness[b]
HOX					
0	53.94	14.00	15.84	1.0j	4.80
1	52.25	13.72	15.17	1.3ij	4.60
2	53.83	12.53	15.39	2.3hi	5.20
3	54.03	14.37	15.70	3.6fg	4.60
4	54.65	13.82	15.20	5.5cd	4.60
5	52.55	12.68	14.32	6.4abc	4.20
LOXDK					
0	55.62	24.66	18.42	7.0a	2.40
1	54.47	25.06	19.87	7.0a	2.40
2	54.02	25.16	18.30	7.0a	2.00
3	53.15	25.61	18.39	5.6bcd	2.60
4	54.17	24.52	18.14	4.9de	2.80
5	52.36	24.54	18.38	4.6def	1.80
LOXL					
0	52.30	24.01	16.56	7.0a	1.41
1	52.44	26.46	18.83	7.0a	2.00
2	54.80	25.27	19.28	7.0a	2.40
3	56.83	23.13	17.69	6.7ab	3.40
4	54.62	25.57	18.49	7.0a	1.60
5	52.34	24.12	18.01	7.0a	2.00
PVC					
0	50.68	25.50	17.62	1.0j	2.21
1	52.42	27.35	20.22	1.1j	3.23
2	56.81	20.67	17.04	1.3ij	3.00
3	53.18	23.41	18.19	2.7gh	3.01
4	53.93	19.92	18.20	3.3g	4.00
5	52.20	21.24	17.83	3.9efg	3.80

abcdefghij Means within a column with a different letter differ ($P < 0.05$).
[a] Score of 1=No discoloration; 2= Slight discoloration 1-19%; 3= Small discoloration 20-39%; 4=Modest discoloration 40-59%; 5=Moderate discoloration 40-59%; 6=Extensive discoloration 80-99%; 7=Total discoloration 100%.
[b] Score of 1=Very rare; 2= Rare; 3= Medium Rare; 4=Medium; 5=Well done; 6= Very well done.

Table 22. Least Squares Means of Cooked Hunter L* a* b* values, Discoloration, and Degree of Doneness for Packaging and Shelf Life Day Effects on *M. Infraspinatus*.

Trt	**L***	**a***	**b***	**Discolor**[a]	**Degree of Doneness**[b]
HOX					
0	54.28	22.99	17.8abcde	1.0f	2.15bcde
1	53.42	22.24	17.76abcde	1.0f	3.17ab
2	52.52	18.20	15.43def	1.0f	2.95abc
3	52.18	20.07	14.74f	3.7b	2.60bcd
4	51.85	18.77	15.62cdef	3.7b	3.76a
5	51.50	19.79	15.49cdef	5.1a	1.16ef
LOXDK					
0	54.93	24.76	18.33ab	5.6a	2.00cdef
1	51.78	24.64	16.76abcdef	1.3ef	1.82cdef
2	52.25	24.88	16.86abcdef	2.0d	1.16ef
3	52.64	23.67	16.53abcdef	2.0d	1.65def
4	51.67	24.51	16.6abcdef	1.3ef	0.97f
5	55.40	22.34	17.09abcdef	1.0f	1.75def
LOXL					
0	53.60	25.39	18.29abc	1.6de	1.58def
1	54.64	23.02	17.04abcdef	1.3ef	1.96cdef
2	54.01	23.77	17.2abcdef	2.0d	1.16ef
3	54.34	23.40	17.35abcdef	2.0d	2.16bcde
4	51.61	23.90	15.93bcdef	1.3ef	1.17ef
5	55.47	23.75	17.11abcdef	1.3ef	2.15bcde
PVC					
0	50.43	23.32	15.2ef	1.0f	1.79cdef
1	51.38	23.23	15.62cdef	1.1f	1.60def
2	54.08	21.64	15.54cdef	1.3ef	1.59def
3	54.53	25.74	19.46a	2.8c	2.02bcdef
4	50.80	25.75	17.96abcd	2.9c	2.16bcde
5	50.55	21.66	16.41abcdef	2.7c	1.58def

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] Score of 1=No discoloration; 2= Slight discoloration 1-19%; 3= Small discoloration 20-39%; 4=Modest discoloration 40-59%; 5=Moderate discoloration 40-59%; 6=Extensive discoloration 80-99%; 7=Total discoloration 100%.

[b] Score of 1=Very rare; 2= Rare; 3= Medium Rare; 4=Medium; 5=Well done; 6= Very well done.

Table 23. Least Squares Means of Cooked Hunter L* a* b* values, Discoloration, and Degree of Doneness for Packaging and Shelf Life Day Effects on *M. Longissimus lumborum.*

Trt x Day	**L***	**a***	**b***	**Discolor[a]**	**Degree of Doneness[b]**
HOX					
0	56.37abcd	15.37	16.72	------	4.41
1	56.83abcd	10.50	14.75	------	5.03
2	53.75defgh	14.11	16.49	------	3.62
3	52.59efgh	15.16	14.63	------	4.22
4	58.85a	13.74	15.63	1.0	3.79
5	55.87abcdef	10.18	14.61	1.3	5.62
LOXDK					
0	51.25gh	25.80	17.58	------	4.02
1	55.71abcdef	26.01	19.91	------	3.63
2	55.95abcdef	26.18	19.69	------	2.07
3	58.35ab	24.67	18.99	------	2.01
4	55.89abcdef	26.03	19.48	5.3	2.02
5	57.59abc	24.88	19.52	3.5	3.23
LOXL					
0	53.35defgh	27.55	19.50	------	2.62
1	54.84bcdefg	25.41	19.26	-------	3.02
2	52.26fgh	24.88	16.53	-------	1.82
3	53.57defgh	24.47	17.00	-------	1.82
4	55.48abcdef	26.42	19.70	7.0	2.61
5	55.99abcdef	24.97	18.19	7.0	2.49
PVC					
0	56.08abcde	24.31	19.18	1.2	3.13
1	55.65abcdef	25.25	19.16	1.1	2.16
2	53.96cdefgh	26.67	18.81	1.3	2.60
3	50.68h	25.90	19.18	2.0	2.74
4	55.89abcdef	24.12	19.71	2.9	3.61
5	55.87abcdef	19.48	18.51	2.8	4.03

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] Score of 1=No discoloration; 2= Slight discoloration 1-19%; 3= Small discoloration 20-39%; 4=Modest discoloration 40-59%; 5=Moderate discoloration 40-59%; 6=Extensive discoloration 80-99%; 7=Total discoloration 100%.

[b] Score of 1=Very rare; 2= Rare; 3= Medium Rare; 4=Medium; 5=Well done; 6= Very well done.

Table 24. Least Squares Means of Cooked Hunter L* a* b* values, Discoloration, and Degree of Doneness for Packaging and Shelf Life Day Effects on *M. Psoas major.*

Trt	L*	a*	b*	Discolor[a]	Degree of Doneness[b]
HOX					
0	55.28	14.79	15.70	1.1h	4.04abcd
1	49.94	15.13	14.54	1.3h	3.91abcde
2	52.41	12.75	15.00	3.1fg	4.76ab
3	51.06	12.18	13.86	3.3fg	4.15abc
4	53.78	14.73	15.79	4.8cde	4.85a
5	54.03	16.09	15.55	5.0bcd	3.38cdefg
LOXDK					
0	55.42	26.26	18.82	7.0a	2.43fghi
1	51.22	24.72	15.78	7.0a	1.32ij
2	55.75	25.51	18.12	7.0a	3.14cdefg
3	55.41	23.94	17.75	7.0a	2.82defg
4	53.13	25.21	17.13	7.0a	2.90cdefg
5	54.37	25.86	18.11	7.0a	3.09cdefg
LOXL					
0	55.28	25.55	18.44	6.0abc	2.31fghij
1	48.58	22.69	13.06	6.3a	1.15j
2	51.71	23.90	16.28	6.0abc	1.44hij
3	56.01	23.96	17.41	6.7a	3.07cdefg
4	49.82	23.87	14.47	6.3ab	1.51hij
5	53.08	24.84	17.15	6.0abc	2.66efgh
PVC					
0	54.79	25.60	18.37	1.0h	3.50bcdef
1	53.54	24.45	16.73	2.0gh	2.10ghij
2	52.09	24.33	17.15	3.1fg	2.11ghij
3	51.93	25.57	17.89	3.9def	1.49hij
4	54.78	19.62	17.19	3.7ef	3.76abcde
5	51.22	22.06	15.94	4.6de	3.30cdefg

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] Score of 1=No discoloration; 2= Slight discoloration 1-19%; 3= Small discoloration 20-39%; 4=Modest discoloration 40-59%; 5=Moderate discoloration 40-59%; 6=Extensive discoloration 80-99%; 7=Total discoloration 100%.

[b] Score of 1=Very rare; 2= Rare; 3= Medium Rare; 4=Medium; 5=Well done; 6= Very well done.

Table 25. Least Squares Means of Cooked Hunter L* a* b* values, Discoloration, and Degree of Doneness for Packaging and Shelf Life Day Effects on *M. Rectus femoris.*

Trt	**L***	**a***	**b***	**Discolor**[a]	**Degree of Doneness**[b]
HOX					
0	53.41	15.56d	16.02	1.4	3.38
1	55.24	14.99d	15.97	1.5	4.62
2	55.57	15.81bcd	17.19	2.3	4.57
3	55.69	13.42d	15.61	2.1	5.31
4	54.58	16.22bcd	16.58	3.3	4.62
5	56.91	13.47d	15.98	3.8	4.58
LOXDK					
0	55.29	25.54a	18.57	5.5	2.62
1	52.07	23.81a	15.73	5.8	2.20
2	56.05	25.9a	19.51	6.0	3.18
3	58.18	23.7a	18.42	6.3	2.40
4	52.17	25.23a	17.08	6.2	2.60
5	55.66	25.04a	17.93	5.7	2.41
LOXL					
0	52.42	24.87a	16.95	6.1	2.20
1	54.48	24.78a	17.24	6.5	2.62
2	57.22	24.76a	18.74	6.2	3.41
3	53.05	23.69a	16.31	6.1	1.60
4	55.41	24.99a	18.06	6.6	3.22
5	54.93	26.1a	18.40	6.3	3.22
PVC					
0	55.45	25.47a	18.84	1.0	2.22
1	57.97	23.42a	18.14	2.2	3.02
2	55.09	23.38a	17.68	2.6	2.42
3	55.35	18.69bc	16.93	3.0	3.42
4	57.88	19.17b	16.96	2.5	3.54
5	55.44	13.88d	15.48	2.6	4.62

abcdefghij Means within a column with a different letter differ ($P < 0.05$).
[a] Score of 1=No discoloration; 2= Slight discoloration 1-19%; 3= Small discoloration 20-39%; 4=Modest discoloration 40-59%; 5=Moderate discoloration 40-59%; 6=Extensive discoloration 80-99%; 7=Total discoloration 100%.
[b] Score of 1=Very rare; 2= Rare; 3= Medium Rare; 4=Medium; 5=Well done; 6= Very well done.

Table 26. Least Squares Means of Cooked Hunter L* a* b* values, Discoloration, and Degree of Doneness for Packaging and Shelf Life Day Effects on *M. Semimembranosus.*

Trt	**L***	**a***	**b***	**Discolor[a]**	**Degree of Doneness[b]**
HOX					
0	52.37	14.11g	16.1ef	1.8hi	4.38abcd
1	53.23	14.29g	16.03ef	2.7gh	4.81ab
2	52.71	13.96g	15.57f	3.7efg	5.01a
3	53.87	20.49def	17.63cdef	4.8cde	3.62cdef
4	53.83	16.85fg	17.29def	6.5ab	4.42abcd
5	53.55	18.79ef	17.59cdef	6.8a	4.62abc
LOXDK					
0	49.75	26.7ab	19.19bcd	7.0a	1.76j
1	52.57	26.46ab	19.6abcd	7.0a	3.41defg
2	54.02	26.07abc	18.54bcd	7.0a	2.01ij
3	53.78	25.62abc	19.5abcd	7.0a	3.22efgh
4	51.12	26.79ab	18.78bcd	3.9def	2.22hij
5	52.05	26.21abc	18.96bcd	3.5fg	2.22hij
LOXL					
0	52.69	26.38abc	19.55abcd	7.0a	2.75fghij
1	52.44	27.05ab	20.87ab	7.0a	3.59cdef
2	49.66	28.45a	19.95abc	7.0a	2.81fghij
3	50.13	24.26bcd	15.98ef	7.0a	2.01ij
4	50.22	28.64a	19.94abc	7.0a	2.41ghij
5	54.64	24.61abcd	18.33cde	7.0a	2.81fghij
PVC					
0	52.53	25.92abc	19.94abc	1.3i	3.15efgh
1	51.90	25.45abc	19.71abc	1.5i	2.99fghi
2	57.54	22.28cde	18.83bcd	2.0hi	3.82bcdef
3	51.10	24.06bcd	19.67abc	4.2def	3.18efgh
4	53.38	25.53abc	21.51a	5.1cd	3.80bcdef
5	52.63	18.48ef	17.67cdef	5.4bc	4.20abcde

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] Score of 1=No discoloration; 2= Slight discoloration 1-19%; 3= Small discoloration 20-39%; 4=Modest discoloration 40-59%; 5=Moderate discoloration 40-59%; 6=Extensive discoloration 80-99%; 7=Total discoloration 100%.

[b] Score of 1=Very rare; 2= Rare; 3= Medium Rare; 4=Medium; 5=Well done; 6= Very well done.

Table 27. Least Squares Means of Cooked Hunter L* a* b* values, Discoloration, and Degree of Doneness for Packaging and Shelf Life Day Effects on *M. Semitendinosus*.

Trt	**L***	**a***	**b***	**Discolor[a]**	**Degree of Doneness[b]**
HOX					
0	59.63	10.02f	15.55i	-----------	4.96
1	59.23	17.57de	18.16efgh	-----------	4.76
2	57.64	15.77e	16.52hi	-----------	3.38
3	59.12	13.83ef	16.81ghi	-----------	3.97
4	59.03	15.56e	16.88ghi	3.7	4.17
5	58.05	15.97e	17.14fghi	4.2	4.36
LOXDK					
0	61.11	22.07bc	20.22abcde	---------	2.70
1	61.11	23.81abc	20.91ab	---------	3.97
2	57.03	25.89ab	19.58abcde	---------	2.82
3	58.06	23.26abc	18.17efgh	---------	2.78
4	60.02	23.55abc	20.1abcde	6.3	3.41
5	57.11	24.76abc	20.68abcd	6.1	3.57
LOXL					
0	59.16	23.82abc	18.97bcdef	---------	0.69
1	60.43	22.61bc	19.82abcde	---------	4.50
2	56.65	24.35abc	18.53defgh	---------	2.64
3	57.07	25.18ab	19.57abcde	---------	3.39
4	58.69	24.47abc	20.81ab	6.7	3.60
5	61.38	22.27bc	20.81ab	7.0	3.96
PVC					
0	56.12	26.83a	21.04a	1.4	3.80
1	56.65	23.69abc	19.02abcdef	2.1	3.33
2	57.55	24.2abc	20.69abc	3.8	3.42
3	56.50	24.76abc	20.22abcde	4.4	3.45
4	57.26	21.05cd	18.65cdefg	5.1	3.38
5	57.05	21.06cd	18.73cdefg	4.7	3.97

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] Score of 1=No discoloration; 2= Slight discoloration 1-19%; 3= Small discoloration 20-39%; 4=Modest discoloration 40-59%; 5=Moderate discoloration 40-59%; 6=Extensive discoloration 80-99%; 7=Total discoloration 100%.

[b] Score of 1=Very rare; 2= Rare; 3= Medium Rare; 4=Medium; 5=Well done; 6= Very well done.

Table 28. Least Squares Means of Cooked Hunter L* a* b* values, Discoloration, and Degree of Doneness for Packaging and Shelf Life Day Effects on *M. Triceps brachii.*

Trt	**L***	**a***	**b***	**Discolor**[a]	**Degree of Doneness**[b]
HOX					
0	49.10	20.64d	16.52	1.3h	2.99cd
1	52.97	11.56e	14.62	1.8h	4.99ab
2	53.35	13.19e	14.99	3.0fg	2.39de
3	52.94	20.77d	17.67	6.1ab	3.78bc
4	52.33	13e	14.70	6.3a	5.19a
5	52.57	14.69e	15.06	6.5a	3.79bc
LOXDK					
0	52.11	27.28a	18.88	7.0a	1.99def
1	50.87	25.78ab	18.11	7.0a	2.38de
2	50.23	25.84ab	17.03	7.0a	0.98f
3	51.11	26.26ab	17.54	7.0a	1.99def
4	52.06	24.94abc	16.98	6.6a	1.79def
5	49.61	26.74a	18.68	4.9cd	1.99def
LOXL					
0	53.43	25.79ab	18.90	7.0a	2.39de
1	50.69	26.41ab	18.14	7.0a	2.40de
2	52.82	27.17a	18.78	5.1bcd	2.19def
3	51.09	25.3abc	16.44	5.2bc	1.20ef
4	51.72	26.11ab	17.76	4.5cde	1.19ef
5	50.74	25.45ab	17.62	4.8cd	2.01def
PVC					
0	53.19	25.38abc	17.88	1.3h	2.46cde
1	51.26	24.78abcd	18.09	1.5h	2.29def
2	56.07	23.16abcd	17.96	2.0gh	2.61cd
3	50.93	26.1ab	17.83	3.0fg	2.01def
4	51.60	22.45bcd	17.30	3.5ef	2.41de
5	49.47	21.42cd	15.72	4.1de	2.80cd

abcdefghij Means within a column with a different letter differ ($P < 0.05$).

[a] Score of 1=No discoloration; 2= Slight discoloration 1-19%; 3= Small discoloration 20-39%; 4=Modest discoloration 40-59%; 5=Moderate discoloration 40-59%; 6=Extensive discoloration 80-99%; 7=Total discoloration 100%.

[b] Score of 1=Very rare; 2= Rare; 3= Medium Rare; 4=Medium; 5=Well done; 6= Very well done.

Table 29. Least Squares Means of Cooked Hunter L* a* b* values, Discoloration, and Degree of Doneness for Packaging and Shelf Life Day Effects on *M. Teres major.*

Trt	L*	a*	b*	Discolor[a]	Degree of Doneness[b]
HOX					
0	55.57	21.27	15.98	1.6ij	2.81cde
1	56.68	23.21	17.39	1.6ij	3.20bcd
2	55.85	23.78	17.02	2.2fghij	2.80cde
3	57.47	21.46	17.92	3.8cde	3.60abc
4	54.83	19.63	15.88	4.6bcd	3.80ab
5	56.16	17.02	15.34	5.3ab	4.20a
LOXDK					
0	55.13	22.85	16.91	3.5cdef	3.00bcde
1	56.53	23.94	16.99	3.3defg	3.00bcde
2	57.83	22.72	16.97	2.7efghi	3.21bcd
3	56.79	23.49	16.67	3.2defgh	2.21ef
4	56.33	23.51	16.58	1.8ghij	2.60def
5	57.39	23.52	17.19	1.6ij	2.60def
LOXL					
0	58.02	22.93	17.46	5.6ab	2.60def
1	59.16	21.66	17.14	6.5a	3.40abcd
2	57.03	22.40	16.75	5.0abc	2.80cde
3	57.56	22.31	17.24	3.2defgh	2.81cde
4	58.23	20.86	16.80	3.5def	3.40abcd
5	57.06	23.24	16.49	2.8efghi	3.00bcde
PVC					
0	56.87	21.04	16.99	1.0j	1.80f
1	56.96	23.75	17.70	1.1j	2.80cde
2	58.92	22.20	18.26	1.7hij	2.80cde
3	56.14	22.41	16.92	1.5ij	2.60def
4	56.60	21.20	16.65	2.7efghi	3.01bcde
5	56.79	23.63	17.32	2.9efghi	3.60abc

abcdefghij Means within a column with a different letter differ ($P < 0.05$).
[a] Score of 1=No discoloration; 2= Slight discoloration 1-19%; 3= Small discoloration 20-39%; 4=Modest discoloration 40-59%; 5=Moderate discoloration 40-59%; 6=Extensive discoloration 80-99%; 7=Total discoloration 100%.
[b] Score of 1=Very rare; 2= Rare; 3= Medium Rare; 4=Medium; 5=Well done; 6= Very well done.

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Speaker Alberta Cattlemen's Association Calgary Alberta, Canada (2003)
The current status of Country Of Origin Labeling in the US
Instructor, Beef 101, Texas Beef Council, College Station, TX (2000-2003)
Responsible for informing industry officials about upcoming trends in beef industry
Teaching Assistant, Animal Science 307, Texas A&M University (2000-2003)
Planned and presented classes/labs every semester for undergraduate animal science majors in meat science issues.
Speaker, Beef 706, Texas Beef Council, College Station, TX (2000-2002)
Spoke to beef industry leaders and trained participants in carcass cutability.
Speaker, International Seminar on the Evaluation of the Zebu Breed as Producers of Meat, American Brahman Breeders Association, Tizimin, Mexico (2001)
Selecting purebred cattle for cutability.
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Provided information regarding quality control in the beef industry.
Speaker, Junior Market Steer Show, Texas Beef Council, Amarillo, TX (2000)
Teaching Assistant, Animal Science 108, Texas A&M University (2000)
Responsible for maintaining records/attendance/ and tests for 400 undergraduate animal science majors.
Teaching Assistant, Graduate/Undergraduate HACCP class, Texas A&M University (2001)
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